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Reference

THE TACTICAL USE OF ATOMIC WEAPONS

UNCLASSIFIED MILITARY EFFECTS

DEPARTMENT OF THE ARMY

MARCH 1955

FOR OFFICIAL USE ONLY

FOREWORD

This pamphlet provides an unclassified basis for the utilization of atomic weapons in courses at the various schools and in training. The effects data herein are based primarily on the unclassified data contained in *The Effects of Atomic Weapons* (U. S. Government Printing Office, September 1950) and in *Radiological Defense, Volume II* (Armed Forces Special Weapons Project, November 1951), but also on other unclassified sources. The methods of casualty and damage estimation herein have been so designed as to provide an understanding of the role of target analysis in the tactical use of atomic weapons without at the same time burdening nonspecialized students with the details of a comprehensive target analysis. These methods, accordingly, are abbreviated and restrictive in scope of application.

It is intended that this text be utilized for classroom purposes in nonspecialized courses. It is applicable to any unclassified casualty and damage estimation provided its limitations are recognized. These limitations, however, render it unsuited for use in preparing target analyses intended to be used as a basis for actual combat operations.

This text has been reviewed by Headquarters, Armed Forces Special Weapons Project, and found to contain neither classified atomic weapon nor atomic weapon effects information, nor RESTRICTED DATA as defined in the Atomic Energy Act of 1946, as amended. It is marked "FOR OFFICIAL USE ONLY" because the damage estimation system it contains is based on certain material produced by the SANDIA CORPORATION under that designation.

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DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C., *11 March 1955*

THE TACTICAL USE OF ATOMIC WEAPONS UNCLASSIFIED MILITARY EFFECTS

Section I. ATOMIC WEAPON EFFECTS

1. General

While the atomic bomb is admittedly a weapon of great power, it is not to be regarded as an absolute weapon—that is to say, it is not a weapon against which there is no defense. Throughout history, the introduction of every new weapon has been followed by the development of defensive measures which have lessened its effectiveness. However, the tactical utilization of atomic weapons requires an understanding of the characteristics and effects of these weapons under various circumstances.

In the event of a future war, a commander must consider the enemy's use of atomic weapons in his own strategic plans or tactical decisions. He must know what precautionary measures will minimize the hazard to his own forces when taking advantage of the situation created by an atomic attack on the enemy. Further, in an emergency, each member of the Armed Services may have to act, possibly without warning, for his own protection.

The explosion of an atomic bomb resembles that of an ordinary high explosive (HE) bomb in the respect that the explosion is due to the rapid release of a large amount of energy in a small space. The energy produced in the HE bomb is due to a chemical reaction, and in the atomic bomb it results from a nuclear process; namely, the fission (splitting) of nuclei of particular forms (isotopes) of the elements uranium or plutonium. However, weight for weight, the energy released in fission is millions of times greater than that produced by a chemical explosive. It is this great concentration of energy, and its rapid liberation, in about a one-millionth part of a second, that accounts for the tremendous power of the atomic bomb.

At least half of the total energy of the bomb contributes to the blast or shock effect. The atomic bomb is thus essentially a blast weapon, like an HE bomb.

The large energy release in a small space in an atomic bomb results in the attainment of a very high temperature, approaching that in the interior of the sun. Consequently, an intense thermal (heat) radiation, carrying about one-third of the total fission energy, emanates from the bomb. A 20-KT burst can produce slight skin burns as far away as 2 miles on a moderately clear day, and the warmth may be felt more than 10 miles away.

A small amount of the bomb energy is carried off by escaping neutrons and gamma rays at the instant of the explosion. The remaining energy of the atomic bomb appears over an extended period of time in the form of gamma and beta radiation from the fission products remaining after the atomic explosion. Because of natural radioactive decay, the activity of the fission products falls off or decays in the course of time.

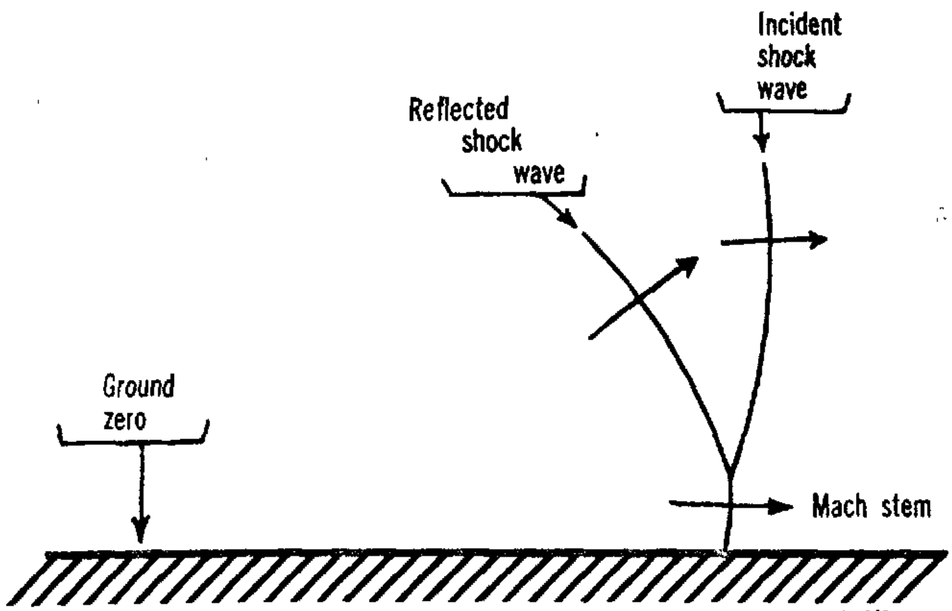
2. Types of Bursts and Types of Effects

Atomic weapons may be burst in the air, on the ground, underground, or underwater. In each case the effects will be different. The effects with which we need be concerned are air blast, thermal radiation, initial nuclear radiation, residual nuclear radiation, and such mechanical effects as crater formation and ground shock.

3. Air Burst

The air burst of an atomic bomb is accompanied by the formation of an intensely hot, luminous sphere of compressed gas called the fireball. As this ascends and cools, an expanding column of smoke forms and rises to a height of from 5 to 8 miles before spreading out to produce the characteristic mushroom-shaped atomic cloud.

The explosion is followed by the formation of a shock wave, moving outward at high speed. The



MACH REFLECTION: FORMATION OF MACH STEM

Mach reflection: Formation of Mach stem.

overpressure (i. e., pressure in excess of atmospheric) in the shock wave and the accompanying wind are responsible for the blast damage to structures. At some distance from ground zero, the direct shock wave fuzes with the shock wave reflected from the surface. This fusion phenomenon is called the Mach effect. The overpressure at the surface is greatly increased by this effect.

Thermal radiation is emitted from the fireball in two pulses. The first lasts for little more than a one-hundredth part of a second and contains a large proportion of ultraviolet radiation. The second pulse, lasting up to 3 seconds and carrying most of the thermal energy emitted by the bomb, consists mainly of visible and infrared rays. Except near ground zero, it is the second radiation pulse which is responsible for skin burns and some incendiary action. This is due to the appreciable absorption of ultraviolet radiation by the intervening air.

The immediate nuclear radiation which reaches the earth from the fireball and the atomic cloud at the time of the explosion consists of gamma rays and neutrons. The lethal range of the neutrons is small in comparison with that of the gamma rays, and so they may be ignored.

The residual radioactivity, consisting mainly of gamma rays and beta particles from the fission products and alpha particles from the uranium or plutonium that has not undergone fission, is that which remains on the ground after the explosion. In the case of an air burst, it will usually be negligible.

Increasing the energy release of the bomb increases the effective ranges of the shock wave, the thermal radiation, and the immediate nuclear radiation, but the *area* of damage always increases less rapidly than the energy release. The effect of the immediate nuclear radiation becomes relatively less important, with respect to blast and thermal radiation, as the energy of the bomb is increased, except for troops in foxholes.

4. Subsurface Burst

In the underwater explosion of an atomic bomb, a huge, hollow column of water and spray is thrown up. The gases from the fireball are vented through the column and form the cauliflower-shaped cloud at the top. As the water from the column falls back to the surface, the base surge is produced. The explosion is accompanied by the transmission of a strong shock wave through the water. Some of the energy of the bomb also appears as air blast.

The thermal and instantaneous nuclear radiations are absorbed in the water, and so have a negligible effect in an underwater burst. But the radioactivity carried by the base surge is important. The radiation dosage received consists of two parts—the transit dose, during the short time the base surge cloud is in transit, and the deposit (or contamination) dose due to the deposition of

radioactive matter. Additional radioactive contamination arises from the fallout from the column and cloud.

An underground burst will result in the formation of a large crater. The earth and rocks hurled upward may weigh over a million tons and a base surge of radioactive dust particles will form when the dirt, etc., falls to the ground. There will be a strong ground shock wave, similar to an earthquake of moderate intensity, and some of the energy of the bomb will also be propagated as air blast.

The thermal and instantaneous nuclear radiations are absorbed by the soil, but the base surge will contribute a transit dose and a deposit dose of radiation, as in an underwater burst. Because of the large amount of dust raised, a considerable fallout is to be expected.

5. Surface Burst

The effects of a surface burst will lie between those of an air burst and a subsurface burst, insofar as they are manifested on the ground. Energy will go into both air blast and ground shock. The thermal and immediate nuclear radiations will be similar to those in an air burst. The base surge and fallout will be less than for a subsurface burst.

6. Effects on Structures and Materiel

Damage to structures and materiel in an atomic explosion is due to blast and shock, heat and fire. Fires may be started by thermal radiation, but most will be extinguished by the blast. The majority of fires will be from secondary causes due to indirect blast effects.

While radioactive contamination does not cause any material damage, it can render a building uninhabitable or equipment unusable for some time because of the hazard to personnel. An air burst is noncontaminating and the only important radiological effect would be on an airplane flying through the atomic cloud.

The base surge and the fallout accompanying a subsurface or surface burst will produce considerable radioactive contamination. In general, rough, worn, and porous surfaces will be more susceptible than smooth, nonporous surfaces. Clean metal and well-painted articles are least vulnerable to contamination.

Reinforced concrete buildings are resistant to blast, shock, and fire; heavy steel-frame structures are relatively invulnerable to blast and shock, but fire weakens the steel members and may cause collapse. Light steel-frame, wooden, and brick buildings are highly vulnerable. Bridges are very resistant to blast. Underground shock will cause sewer, gas, and water mains to suffer severely, but electric mains will not be greatly affected. The rupture of gas mains may cause fires to start.

Unarmored vehicles are easily damaged, as also are lightly constructed electrical and electronic devices of all kinds. Heavy equipment, such as machine tools, motors, generators, etc., will be injured by debris and by fire. Medium and heavy tanks and armored cars are very resistant to blast. Heavy weapons also will stand up well. In all cases, however, exposed parts and equipment will suffer.

Naval craft are, on the whole, not very vulnerable to blast or shock. Fairly close to surface zero, hulls may be damaged by underwater shock. Topside equipment is likely to suffer from blast and antennas are especially sensitive. No serious damage to machinery is expected from blast, but rupture of foundations due to shock will render it useless. Main feed and main steam lines, and boiler brickwork are also sensitive to shock.

Because of their design, aircraft, especially fighter type planes, can withstand moderate blast and shock. Large planes have a considerable surface area exposed to blast; as a result they may suffer damage from tipping or weathercocking. The powerplant, armament, and oxygen, hydraulic, fuel, and oil systems are resistant to blast. Interior equipment will be protected if the exterior of the craft is intact.

7. Effects on Personnel

Casualties from an atomic explosion will be due to blast and shock, burns, and nuclear radiation. Primary blast injuries, caused by direct action of air blast, will be rare. Mechanical injuries, caused by collapsing buildings, missiles, etc., are a secondary result of blast and shock. Such injuries will be experienced in atomic explosions of all types.

Primary (or flash) burns are a direct result of thermal radiation from the bomb, while secondary burns are caused by fires subsequent to the explosion. Flash burns will be common after an air burst, but they will be negligible after subsurface bursts because the thermal radiation is absorbed by water or earth. In a 20-KT air burst burns may occur as far as 2 miles from ground zero.

Radiation injury may be due to external radiation, reaching the body from outside, or to internal radiation, resulting from radioactive material taken into the body. A dose of external radiation can be received in a short time (acute) or over an extended period (chronic). An acute dose can be caused by nuclear radiation emitted from the bomb in an air burst, or from the base surge in a subsurface burst. A chronic dose can be received from the residual or lingering radiations from contaminated surroundings.

The first symptoms of radiation sickness are nausea and vomiting. These symptoms may be followed by a latent period, after which further symptoms appear. An acute dose of 650 roentgens or more, over the whole body, will prove fatal to nearly all exposed individuals; about 50 percent of those receiving 450 roentgens will die; and most of those receiving 200 roentgens will become sick, but nearly all should recover. A chronic dose, spread over a considerable time, is less harmful than an acute dose of the same quantity of radiation.

Residual radiation may be either an external or an internal hazard. The *external* hazard from gamma radiation is important, but that caused by beta and alpha particles is not significant. On the other hand, both beta and alpha emitters can, under unusual circumstances, represent a long-term *internal* hazard if they enter the body.

8. Protection of Personnel

Strong structures, including foxholes, provide the best shelter against blast, and any opaque material will protect against thermal radiation. Protection from gamma radiation requires appreciable thicknesses of material. Dense substances, such as steel, are most effective in this respect.

Under emergency conditions it might not prove possible to adhere to the strict peacetime exposure levels for radiation dosage. As in all military operations, a commander must take a calculated risk based on available information.

Partial protection from an atomic attack may be obtained in existing structures—ashore and afloat. Various types of simple earth shelters, including slit trenches and foxholes, can be effective against an air burst. Dispersion, if practical, will decrease the number of casualties, and in special circumstances a smoke screen might reduce the incidence of skin burns.

An individual caught in an attack can take immediate self-preservation measures, and after the attack he should be prepared to render first aid to others.

While special, disposable clothing is desirable for operations in a contaminated area and for decontamination work, ordinary military clothing may be adapted to provide an effective substitute. Personnel caught in a contaminating attack should be monitored and, if necessary, decontaminated as soon as possible. Emergency decontamination centers may be set up in the field. In addition, change stations should be available in a rear area or on board ship.

Food and water can appear to be appreciably radioactive as measured by many portable instruments (called radiac instruments) and, nevertheless, may still be acceptable for consumption under emergency conditions.

Section II. ASSUMED ATOMIC WEAPONS AND DELIVERY SYSTEMS

9. General

Atomic weapons are rated in terms of their potential effective energy release expressed in equivalent kilotons of TNT. One kiloton is 1,000 tons. Hence, a weapon capable of releasing an effective amount of energy equivalent to 20,000 tons of TNT is referred to as a 20-kiloton (20-KT) weapon. In the series of weapons assumed for the purposes of this text there are seven weapons ranging from 2-KT to 500-KT (fig. 1).

10. Burst Capabilities

The seven atomic weapons are assumed to have burst capabilities as follows:

a. High Air Burst. All weapons are given this capability. The height of burst chosen is based on 2,000 feet for the 20-KT weapon. For other yield weapons the "high air burst" has been so selected as to be in ratio to 2,000 feet according to the cube root of the ratio of their yield to 20-KT.

b. Low Air Burst. All weapons are given this capability. The height of burst chosen is based on one and one-half times the fireball radius for the 20-KT weapon. This is 675 feet for the 20-KT weapon. For the other yields it has been assumed that fireball volume is directly proportional to yield.

c. Surface Burst. Only the CHARLIE (20-KT) weapon has been given this capability. A surface burst is defined as a burst taking place above ground level but within 50 feet of the surface of the ground.

Weapons		Capability for type of burst					Available delivery systems								
		Air burst					Artillery		Free rocket		Guided missile		Air delivery		
Type	Yield (KT)	High [1]	Low [2]	Surface burst	Underground burst	Prepositioned burst	Maximum range (yd)	CEP [3] (yd)	Range (miles) (assumed)	CEP (yd)	Range (miles) (assumed)	CEP (yd)	High-altitude release CEP (yd)	Low-altitude release CEP (yd)	Prepositioned (CEP always zero)
ABLE	2	Yes	Yes	No	No	No	30, 000	[3] 0	No capability		No capability		No capability	500	No capability
BAKER	15	Yes	Yes	No	No	No	30, 000	[3] 0	10–25	500	20–150	500	No capability	500	No capability
CHARLIE	20	Yes	Yes	Yes	Yes	Yes	30, 000	[3] 0	10–25	500	20–150	500	1, 000	500	[4]
DOG	75	Yes	Yes	No	No	No	No capability		10–25	500	20–150	500	1, 000	500	No capability
EASY	100	Yes	Yes	No	No	No	No capability		10–25	500	20–150	500	1, 000	500	No capability
FOX	200	Yes	Yes	No	No	No	No capability		No capability		No capability		1, 000	No capability	No capability
GEORGE	500	Yes	Yes	No	No	No	No capability		No capability		No capability		1, 000	No capability	No capability

[1] Scaled from 2,000 ft for the 20-KT weapon.
[2] 1½ times radius of fireball (fireball volumes assumed proportional to yield)
[3] Use Zero CEP in all instances except troop safety. Use CEP = 100 yards for troop safety.
[4] Normally used only for surface or underground bursts, but see notes to figures 2, 3, and 4

Figure 1. Weapon-burst-delivery capabilities.

d. Underground Burst. The only weapon given this capability is the CHARLIE (20-KT) weapon. It has been estimated that if a 20-KT bomb were dropped from the air and penetrated sandy soil to a depth of 50 feet before detonating, the resulting crater would be 350 feet deep and 400 yards in diameter.

11. Assumed Delivery Systems

The delivery systems assumed available for the series of weapons are as follows. For a tabulation of delivery systems applicable to individual weapons, see figure 1.

a. Air Delivery.

(1) *High-Altitude Release.* This is defined as high-altitude level-flight bombing from altitudes in excess of 25,000 feet.

(2) *Low-Altitude Release.* This is defined as any type of air delivery other than high-altitude release; it includes low-altitude level-flight bombing, dive bombing, and toss, loft, or glide bombing.

b. Artillery Delivery. This is defined as delivery by artillery. For assumed maximum range, see figure 1.

c. Rocket Delivery. This is defined as delivery by unguided preset rockets. For assumed maximum and minimum range capabilities, see figure 1.

d. Guided Missile Delivery. This is defined as delivery by guided missiles irrespective of the guiding principle utilized. See figure 1 for assumed maximum and minimum ranges.

e. Prepositioned Delivery. This is defined as actual placement of the weapon at the desired point of detonation for firing by some form of remote-control, or for firing by some form of time-clock control. For the purposes of this text it is assumed that prepositioned weapons may be fired by remote-control at any time during a period of 7 days after placement. Only the CHARLIE weapon has been given this capability because only this weapon has been given a surface-burst and underground-burst capability.

12. Delivery Systems' Probable Delivery Error

No delivery system is capable of delivery without error in all cases. Different delivery systems are liable to have different types of delivery (or impact) distribution patterns. Distribution patterns are either generally circular (called circular delivery), or generally elliptical (called noncircular). For simplicity it has been assumed that all of the assumed delivery systems have circular distribution patterns. This is a reasonable assumption, especially when the direction of flight for air delivery is unknown, and when the gun-target (or launching site-target) line is unknown. For circular delivery patterns, the probability of an error in delivery is expressed by what is referred to as CEP (circular error probable). By definition 1 CEP is the radius of a circle which will contain 50 percent of all bombs dropped (or missiles launched). In the instance of artillery delivery this radius is so small that, for the weapons assumed capable of this delivery, the CEP is assumed as zero, *except that for troop safety risk determinations a CEP of 100 yards should be used* (sec. VI). For a tabulation of CEP's applicable to the various weapons and delivery systems, see figure 1.

Section III. EFFECTS RADII (R_e) FOR THE ASSUMED ATOMIC WEAPONS

13. General

In determining the extent of militarily effective damage from atomic detonations it is necessary to know the types of effects and the effects intensities to which the various types of military targets are responsive. Militarily effective damage can be categorized as severe, moderate, or light. Rarely will light damage suffice in the instance of tactical-type targets, light damage being defined as damage insufficient to prevent the use of an item although some repairs may be required to restore it completely. Although moderate damage is often of considerable military significance, the extent to which severe damage will result is an effective indicator of the success of any given detonation; severe damage being defined as that which removes the target's military significance by rendering it useless for military purposes either permanently or until major repairs are accomplished. For this reason, and for simplicity, this text considers severe damage against enemy targets only. It does not consider moderate damage at all. It is concerned with light damage only as it affects troop safety (par. 44).

14. Types of Target Considered

Generally speaking there are two types of tactically significant targets for atomic weapons: personnel and materiel. There are numerous types of materiel, each of which is most responsive

to a particular type of effect and effects intensity. The vulnerability of personnel depends on the type of effect and varies with the degree of shielding available (and utilized), and with the amount of special protection afforded (such as protective clothing). For any given amount of shielding and special protection, there is a specific type of weapon effect to which both personnel and materiel are most vulnerable. In addition, there is a specific effect intensity required to produce a significant amount of militarily effective damage. In the tabulations which follow (figs. 2, 3, and 4), the types of tactically significant targets have been grouped, for simplicity, into a minimum number of categories. For each of these categories, and for each of the assumed weapons and burst capabilities (fig. 1), these tabulations indicate the distance (R_e) from ground zero to which severe damage may be expected to result. (Ground zero is defined as the point on the ground which lies directly below the point of burst of the weapon; or, in the case of an underground burst, which lies directly above the point of burst.) There is a separate tabulation for each type of weapon effect.

15. Air-Blast Effects

(fig. 2)

The air-blast effects of the seven assumed weapons for each of their various burst capabilities are shown in figure 2. It indicates the effects radii (R_e) applicable to air blast for the several general types of tactically significant targets. In each instance these radii are in terms of distance in yards from ground zero to which severe damage may be expected to result. Each distance given is an average for the types of targets to which it is designated applicable. In some of the instances these averages have been designated applicable to a wide range of conditions. This is a simplifying consideration which would not be considered valid in a comprehensive target analysis (see foreword).

a. Built-up Areas and Personnel in Built-up Areas (i. e., cities). Built-up areas (i. e., cities) are vulnerable to primary blast effects. Personnel in cities are vulnerable to secondary blast effects (par. 7). Accordingly, it is feasible to use the same air-blast effects radii both for the destruction of structures constituting the city and to cause personnel casualties in the city.

b. Command Posts. This is applicable to field-type command posts (in contrast to command posts in cities, i. e., built-up areas) which have been given a measure of protection by digging-in. The effects radii given are an average for all facilities of a command post. For command posts in built-up areas, use the effects radii for built-up areas.

c. Trucks (All Types). The applicable weapon effect is primary blast. All types of trucks are included provided they are exposed. Dug-in trucks may be expected to suffer less damage than those completely exposed. However, some damage will result since air blast penetrates all openings. For dug-in trucks, see figure 2, note 4.

d. Tanks and Armored Vehicles (All Types). The applicable weapon effect is primary blast. All types of tanks and armored vehicles are included provided they are exposed. For dug-in tanks and armored vehicles, see figure 2, note 4.

e. Artillery (All Types). The applicable weapon effect is primary blast. All types of artillery are included provided they are exposed. For dug-in artillery, see figure 2, note 4.

f. Communications Equipment. The applicable weapon effect is primary blast. The types of communications equipment to which this category is intended to be applicable are radios, radars, switchboards, telephones, and all other similarly constructed sensitive equipment associated with communications, provided, in every instance, it is exposed to the air-blast effect. If this equipment is located within a built-up area (i. e., city), it could be destroyed with certainty only by destroying the built-up area. For dug-in communications equipment, see figure 2, note 4.

g. Bridges. Weapon effects radii are given both for railway and for highway bridges, separately for two different bridge lengths (not span lengths) in each case. These are average figures for 1-track and 2-track railway bridges, and for 2-lane and 4-lane highway bridges. In a comprehensive target analysis, effects radii applicable to the specific type of bridge under consideration for atomic attack should be used rather than data averaged for simplicity reasons.

h. Maintenance Areas. The effects radii given in figure 2 are an average for the many types of materiel usually located in maintenance areas. These radii are to be considered equally applicable to supply points, division service areas, intransit depots, and supply complexes of all kinds. For dug-in materiel in maintenance areas, see figure 2, note 4.

i. Port Facilities. The effects radii given in figure 2 are an average for the many types of facilities in a port. These include buildings, materials-

Weapon type and yield	Type burst	Built-up areas and personnel in built-up areas [1] (i. e., cities)	Command posts [2]	Materiel damage [3, 4]: Trucks (all types)	Materiel damage: Tanks and armored vehicles	Materiel damage: Artillery (all types)	Materiel damage: Communi-cations equipment	Bridge destruction: Railroad 0–350 feet	Bridge destruction: Railroad 350–550 feet	Bridge destruction: Highway 0–250 feet	Bridge destruction: Highway 250–550 feet	Mainte-nance areas [4]	Port facilities
ABLE (2-KT)	High air	825	1, 400	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	370
	Low air	620	1, 050	210	85	175	450	280	210	175	260	280	280
BAKER (15-KT)	High air	1, 610	2, 740	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	730
	Low air	1, 210	2, 060	410	170	340	890	545	410	340	510	545	545
CHARLIE (20-KT)	High air	1, 775	3, 000	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	800
	Low air	1, 330	2, 250	450	190	375	975	600	450	375	565	600	600
	Surface	1, 330	2, 250	450	190	375	975	600	450	375	565	600	600
	Underground [6]	885	1, 500	300	125	250	650	400	300	250	370	400	400
	Prepositioned [7]	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)	(7)
DOG (75-KT)	High air	2, 760	4, 680	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	1, 250
	Low air	2, 070	3, 520	700	290	580	1, 520	935	700	580	875	935	935
EASY (100-KT)	High air	3, 020	5, 160	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	1, 370
	Low air	2, 280	3, 860	770	320	640	1, 670	1, 030	770	640	970	1, 030	1, 030
FOX (200-KT)	High air	3, 840	6, 480	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	1, 730
	Low air	2, 880	4, 860	975	405	810	2, 100	1, 300	975	810	1, 215	1, 300	1, 300
GEORGE (500-KT)	High air	5, 200	8, 800	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	(5)	2, 340
	Low air	3, 900	6, 700	1, 330	550	1, 090	2, 850	1, 750	1, 330	1, 090	1, 650	1, 750	1, 750

[1] Based upon destruction of structures.

[2] Applicable to the field-type command posts given dug-in protection. For command posts in cities use effects radii for built-up areas.

[3] Item damaged seriously enough to render it useless either permanently or until major repairs are accomplished.

[4] For dug-in materiel, use an effects radius equal to *one-half those given in this figure.*

[5] Blast damage from high air-bursts against "materiel," "bridges," and "maintenance areas" is considered militarily negligible.

[6] 50-foot depth of penetration.

[7] *a.* Use surface-burst effects radii when prepositioned on the surface or at depths up to 25 feet.

b. Use underground-burst effects radii when prepositioned underground (or underwater) at depths from 26 to 50 feet.

c. Do not preposition underground (or underwater) at depths greater than 50 feet.

d. Use surface-burst effects radii when prepositioned above ground in buildings regardless of building height.

Figure 2. Effects radii (R_e) for air blast.

(Distance in yards from ground zero)

handling equipment, etc. For military equipment and supplies being handled in a port use effects radii for maintenance areas.

16. Terminal Radiation Effects (fig. 3)

The thermal radiation effects radii applicable to four types of personnel targets of tactical significance are shown in figure 3. No materiel targets are included in this tabulation because thermal radiation, by itself, will cause but superficial damage to component parts of trucks, tanks, armored cars, artillery, communications equipment, and bridges. In the case of field command posts, maintenance areas, and port facilities, damage caused by thermal radiation will be militarily significant in many individual instances; but, on the average, the greatest contribution to damage is likely to be caused by blast. In the case of personnel, however, thermal radiation is a highly significant effect. The thermal effects radii shown in figure 3 are premised on causing immediate casualties who will require immediate evacuation. In the passage of thermal radiation through the air, from the exploding bomb to the earth's surface, the thermal radiation undergoes a decrease in intensity. This reduction is due mainly to the molecules of air and the molecules of water vapor in the air, and to the particles of dust, smoke, etc., in the atmosphere. This reduction consequently will be greater on a hazy or foggy day than on a clear day. In figure 3, only two atmospheric conditions are assumed: haze present, visibility about 2 miles; and atmosphere clear, visibility about 20 miles. In a comprehensive target analysis the actual visibility would have to be taken into account.

a. Troops in Open. This applies to troops above ground, in random orientation and normal battlefield dress, but with no thermal shielding. Effects

Weapon type and yield	Type of burst	Personnel [1]			
		Troops in open 2-mi Vis [2]	Troops in open 20-mi Vis [2]	Troops in foxholes [3] 2-mi Vis [2]	Troops in foxholes [3] 20-mi Vis [2]
ABLE (2-KT)	High air	[4] 710	780	[4] 360	[4] 430
	Low air	[4] 740	810	[4] 145	[4] 145
BAKER (15-KT)	High air	1, 320	1, 900	960	1, 055
	Low air	1, 440	1, 980	[4] 180	[4] 180
CHARLIE (20-KT)	High air	1, 325	2, 000	1, 040	1, 150
	Low air	1, 460	2, 105	[4] 395	[4] 395
	Surface	1, 400	2, 010	[4] 265	[4] 265
	Underground	0	0	0	0
	Prepositioned	([5])	([5])	([5])	([5])
DOG (75-KT)	High air	1, 930	3, 640	1, 560	1, 810
	Low air	2, 200	3, 780	[4] 605	[4] 605
EASY (100-KT)	High air	2, 250	4, 150	1, 645	2, 000
	Low air	2, 460	4, 260	[4] 670	[4] 670
FOX (200-KT)	High air	2, 580	5, 500	2, 045	2, 510
	Low air	2, 920	5, 650	[4] 845	[4] 845
GEORGE (500-KT)	High air	3, 160	7, 500	2, 500	3, 110
	Low air	3, 650	7, 700	[4] 1, 145	[4] 1, 145

[1] Basis is immediate casualties.

[2] Abbreviation for visibility.

[3] Troops in medium to deep foxholes.

[4] Initial gamma radiation effects radius exceeds the thermal radiation effects radius—see figure 4.

[5] *a.* Use underground-burst effects radii when prepositioned underground.
b. Use surface-burst effects radii when prepositioned on the surface.
c. Use surface-burst effects radii when prepositioned less than 675 feet above ground in buildings.
d. Use low air-burst effects radii when prepositioned more than 675 feet above ground in buildings.

Figure 3. Effects radii (R_e) for thermal radiation.

(Distances in yards from ground zero)

radii for personnel in the open are assumed applicable to personnel in woods but only to the extent that the woods do not provide thermal shielding. The thermal effect is a line-of-sight effect. Consequently, if 1,000 troops are in a woods which offers 50-percent thermal shielding, then 500 troops are to be considered shielded from thermal effects and 500 troops are to be considered not shielded, i. e., in the open.

b. Troops in Foxholes. This applies to troops in 1-man or 2-man medium-to-deep uncovered foxholes of random orientation. The vulnerability of troops in foxholes is dependent on the intensity of thermal radiation present at the surface of the ground, and on the angle of incidence of the thermal ray. This explains the shorter effects radii for the lower burst heights, and the equal effects radii at the lower burst heights for the two visibility conditions.

17. Initial Gamma Radiation Effects (fig. 4)

The initial gamma radiation effects radii applicable to five types of personnel targets of tactical significance are shown in figure 4. No materiel targets have been included in this tabulation because initial gamma radiation is not effective against other than personnel targets. These effects radii are applicable to personnel receiving initial gamma radiation over the whole body at one time, and do not take into effect the influence of residual radiation to which these same personnel might also be exposed. The effects radii shown in figure 4 are premised on personnel receiving a whole-body (as contrasted to only on a part of the body) dose of initial gamma radiation sufficient to cause nausea and vomiting in all personnel within 4 hours. Evacuation of all personnel receiving this dose can be expected to be required on the first day. In addition, up to 100

Weapon type and yield	Type burst	Personnel [1]			
		Troops in open or woods	Troops in foxholes [2]	Troops in tanks [3] or light bunkers [3]	Troops in heavy bunkers [4]
ABLE (2-KT)	High air	765	515	340	0
	Low air	795	565	410	210
BAKER (15-KT)	High air	[5] 1,090	[5] 800	600	175
	Low air	[5] 1,240	995	840	620
CHARLIE (20-KT)	High air	[5] 1,150	[5] 810	630	240
	Low air	[5] 1,310	1,025	890	670
	Surface	[5] 1,330	1,050	920	710
	Underground	0	0	0	0
	Prepositioned	([6])	([6])	([6])	([6])
DOG (75-KT)	High air	[5] 1,260	[5] 1,200	1,110	0
	Low air	[5] 1,590	1,345	1,125	905
EASY (100-KT)	High air	[5] 1,270	[5] 1,205	525	0
	Low air	[5] 1,660	1,320	1,190	995
FOX (200-KT)	High air	[5] 1,090	[5] 710	0	0
	Low air	[5] 1,740	1,525	1,315	1,060
GEORGE (500-KT)	High air	[5] 800	[5] 0	0	0
	Low air	[5] 2,000	1,570	1,475	1,255

[1] Basis is sickness in 4 hours and up to 100 percent eventual deaths. Survivors ineffective for 6 months.

[2] *Troops in medium-to-deep uncovered foxholes.*

[3] 4 inches of steel assumed. Also applicable to troops protected on all sides by 12 inches of concrete or 20 inches of earth.

[4] 30 inches of earth or 18 inches of concrete, or 6 inches of steel, assumed on all sides.

[5] The effects radius for thermal radiation exceeds the effects radius for initial gamma radiation—does not apply to troops in woods.

[6] *a* *Use underground-burst effects radii when prepositioned underground.*

b Use surface-burst effects radii when prepositioned on the surface.

c Use surface-burst effects radii when prepositioned less than 675 feet above ground in buildings.

d Use low air-burst effects radii when prepositioned *more than 675 feet* above ground in buildings.

Figure 4. Effects radii (R_e) for initial gamma radiation.

(Distances in yards from ground zero)

percent eventual deaths can be expected, with any survivors being ineffective for full military duty for over 6 months.

a. Troops in Open or in Woods. This is applicable to troops above ground who are provided with only incidental protection against gamma radiation.

b. Troops in Foxholes. This is applicable to troops in 1-man or 2-man medium-to-deep uncovered foxholes of random orientation.

c. Troops in Tanks or Light Bunkers. This is applicable to troops in tanks or light bunkers, who thus are protected *on all sides* by an assumed 4 inches of steel, or who are protected *on all sides* by 12 inches of concrete or 20 inches of earth.

d. Troops in Heavy Bunkers. This is applicable to troops in fortifications giving *all-around* protection from initial gamma radiation equivalent to 18 inches of concrete, or 30 inches of earth, or 6 inches of steel.

18. Cratering and Ground Shock Effects (fig. 5)

a. Underground Burst. The only weapon given an underground-burst capability is the CHARLIE, (20-KT) weapon. It has been estimated that, if a 20-KT atomic bomb were dropped from the air and penetrated 50 feet into sandy soil before detonation, it would produce a crater 350 feet deep and 400 yards in diameter. Residual nuclear radiation would result, which is discussed in section IV. Ground shock would also result. Calculations indicate that a destructive earth-shock effect would probably occur to a radial distance of about 2 crater radii or about 400 yards from ground zero. This destructive earth-shock effect would be applicable only to structures, and not to materiel resting on the ground.

b. Surface Burst. The CHARLIE (20-KT) weapon is also the only weapon given a surface-burst capability. Craters, and the attendant residual radiation problem, also result from surface bursts. It has been estimated that, whereas 25 percent of the detonation energy will appear in ground shock from an underground burst, only 15 percent will appear in ground shock from a surface burst. Consequently, crater radii and ground-shock effects radii for a surface burst will be less than for an underground burst of equal energy release.

Weapon type and yield	Type burst	Crater dimensions		Ground shock radii of effects [1] (yards)
		Depth (feet)	Radius (yards)	
ABLE (2-KT)	Air	0	0	0
BAKER (15-KT)	Air	0	0	0
CHARLIE (20-KT)	Air	0	0	0
	Surface	[2] 200	140	280
	Underground	350	200	400
	Prepositioned	[3]	[3]	[3]
DOG (75-KT)	Air	0	0	0
EASY (100-KT)	Air	0	0	0
FOX (200-KT)	Air	0	0	0
GEORGE (500-KT)	Air	0	0	0

[1] Applicable only to structures.
[2] Assumed
[3] Use data for air, surface, or underground burst as appropriate.

Figure 5. Effects radii (R_e) for cratering and ground shock.

Section IV. RESIDUAL RADIATION

19. General

The residual radioactivity is that which remains after the immediate effects of the detonation are over. It consists of gamma rays and particles from the fission products which have escaped fission. When the radioactive particles of fission products collide with dust particles they may adhere. Consequently, if there are dirt particles in the atomic cloud they may become contaminated with radioactivity. When the atomic cloud has dispersed, the radioactive particles will fall back to earth. This effect is referred to as *fallout*. It is because of the hazard it represents that fallout must be considered. In an air burst the fallout is a negligible hazard. But in a surface burst or an underground burst, because of the great amount of dust drawn up by the burst, fallout is not at all negligible.

20. Underground Burst

In an underground burst a considerable volume of material is thrown into the air. Much of this material will fall directly back into the crater because of its weight. Some will fall out at greater distances from ground zero. Figure 6, which has been patterned after BIKINI BAKER data revised to accord to estimates for an underground burst, presents an estimate of the radiation dosage rate in roentgens per hour on the ground 1 hour after an underground burst of weapon CHARLIE. Figure 6 assumes a wind of 5 miles per hour. If the underground detonation should be accompanied, or followed, by high winds due to natural causes, large amounts of contaminated dirt may be carried away, as in a duststorm. If for any reason much of this should fall in one area, perhaps carried down by rain, a serious radiation hazard might be created. The possibility of such an occurrence must be kept in mind. For simplicity no estimates of residual radiation for other than a 5-mile wind velocity are presented in this text.

21. Surface Burst

In a surface burst a lesser volume of material is thrown into the air than in an underground burst. A distinct problem of residual radiation, nevertheless, must be reckoned with. Figure 7, which is based on ALAMAGORDO data revised for a 5-mile-per-hour wind, presents an estimate of the radiation dosage rate in roentgens per hour on the ground 1 hour after a surface burst of weapon CHARLIE. Again, if high winds should accompany or follow the detonation, a serious radiation hazard might be created. For simplicity no estimates of residual radiation for other than a 5-mile wind velocity are presented in this text.

22. Decay of Fission Product Activity

The direct products of fission start to decay as soon as they are formed. They continue to decay until ultimately the activity of the fission products becomes negligible. The rate at which they decay has been determined from experimental measurements. Figure 8, "Chart for estimation of dose rate at various times after an atomic explosion," is based on the results of these measurements and enables determination of the dosage rate in roentgens per hour at any given time provided only that the dosage rate 1 hour after detonation is known.

a. First Example of Use of Figure 8. At 1¼ hours after an atomic explosion, the radiation dose rate at a certain place, due to fission products, was found to be 8 roentgens per hour. What would it be after 24 hours?

The arrow (1) in the reproduction of figure 8 below indicates the time "1¼ hours" after the explosion, and arrow (2) shows the dose rate "8 roentgens per hour." These establish a point marked *a*, which represents the information given. A line through *a*, parallel to the others in the figure, will then indicate the change of radiation intensity with time at the place under consideration. The dose rate at 24 hours after the explosion is found by following this line from *a* to *b*, where it meets the vertical line for "24 hours" after the explosion, indicated by arrow (3). The dose rate at *b*, which is the required answer, is then obtained by finding the corresponding reading on the vertical scale Following the horizontal line from *b* to *c*, this is seen to be 0.28 roentgens per hour.

b. Second Example of Use of Figure 8. At 30 minutes after an atomic explosion, the radiation dose rate, due to fission products, was found to be 260 roentgens per hour. How long will it be necessary to wait until the dose rate at this place falls to 1 roentgen per hour?

The arrow (1) in the reproduction of figure 8 below indicates "0.5 hour," i. e., 30 minutes, after the explosion, and arrow (2) shows the dose rate

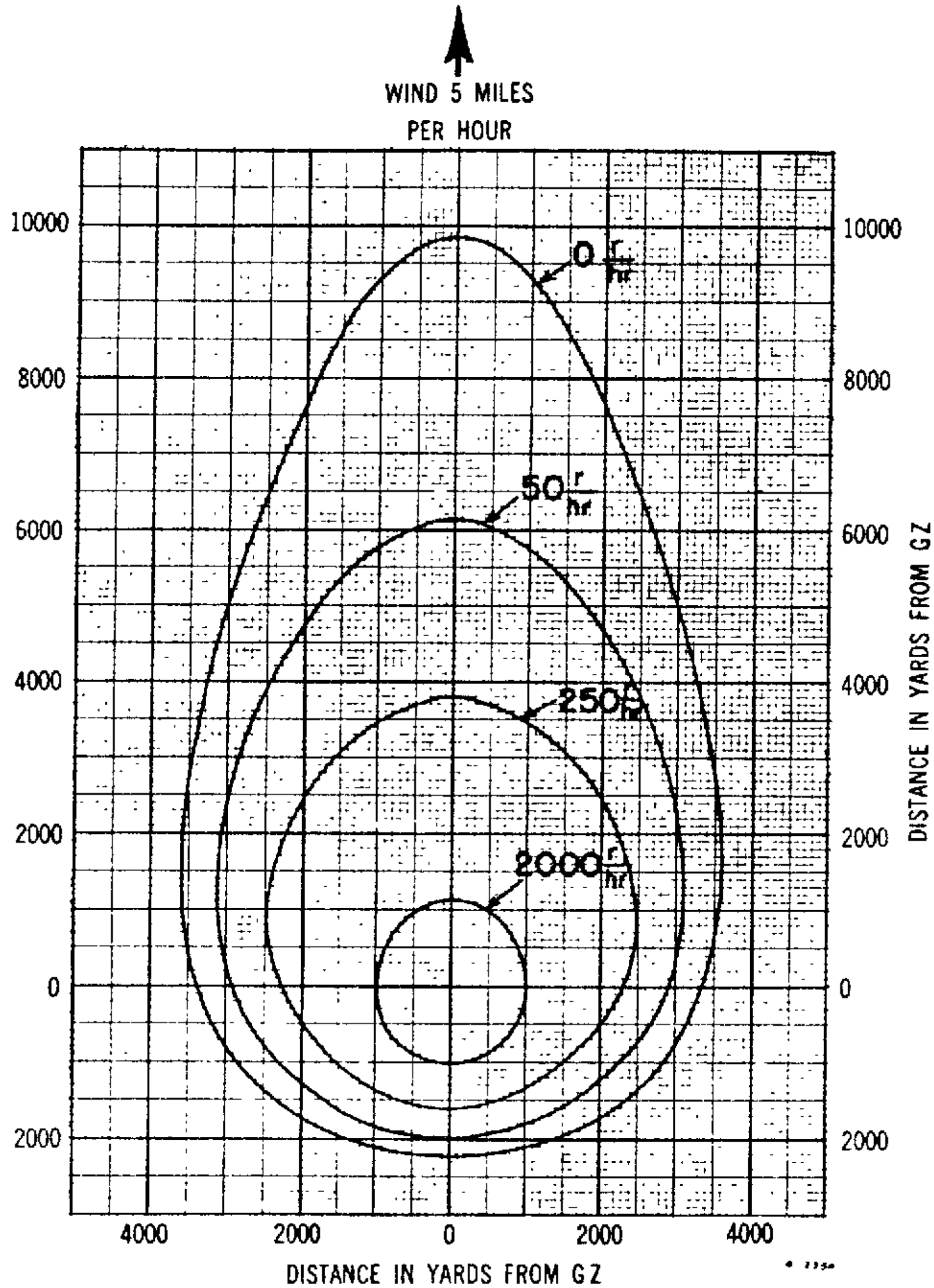


Figure 6. Estimated radiation dosage rate in roentgens per hour on ground 1 hour after detonation of a 20-KT underground burst.

(Derived from BIKINI BAKER)

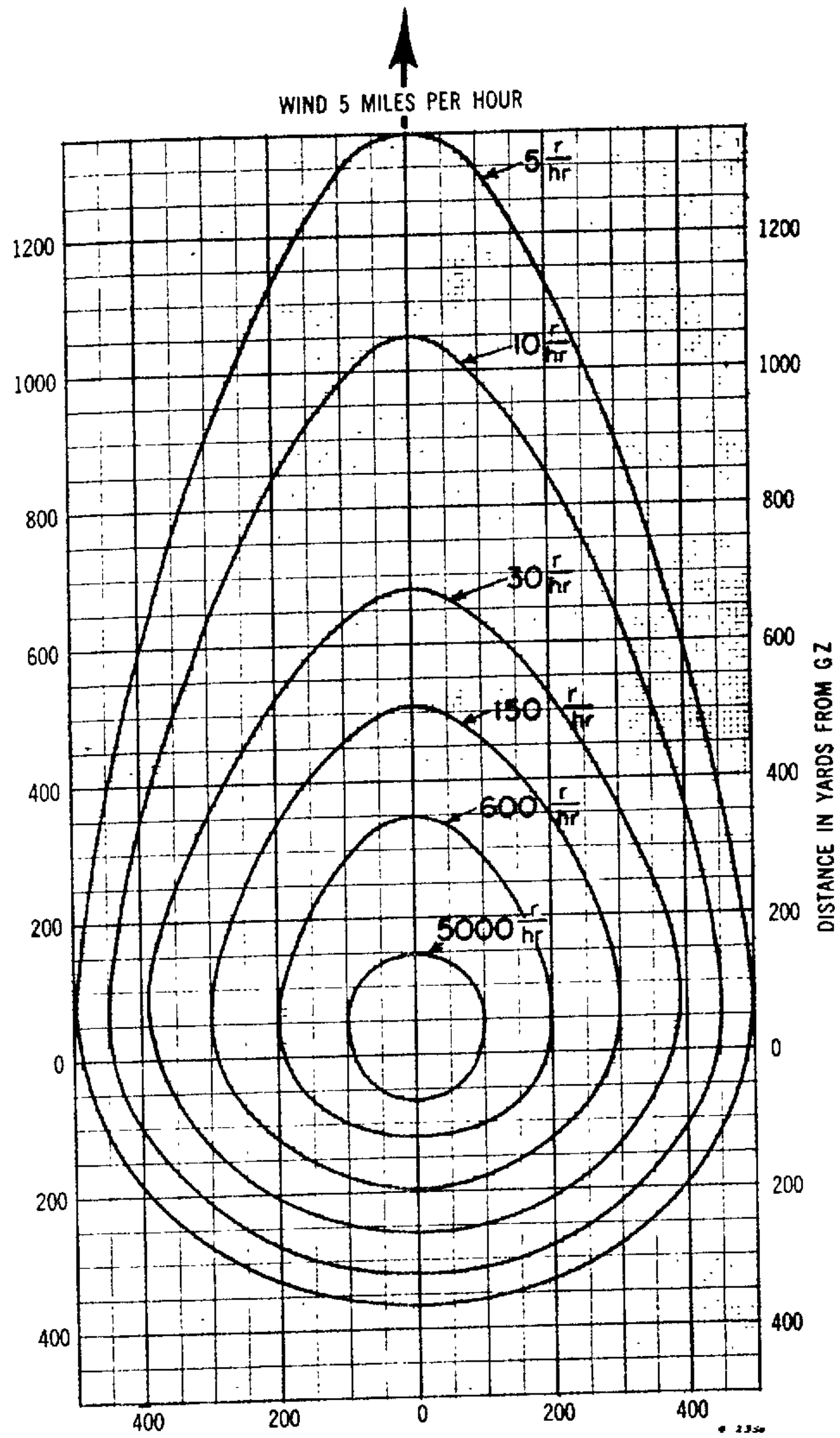


Figure 7. Estimated radiation dosage rate in roentgens per hour on ground 1 hour after detonationof a 20-KT surface burst.

(Derived from ALAMAGORDO DATA)

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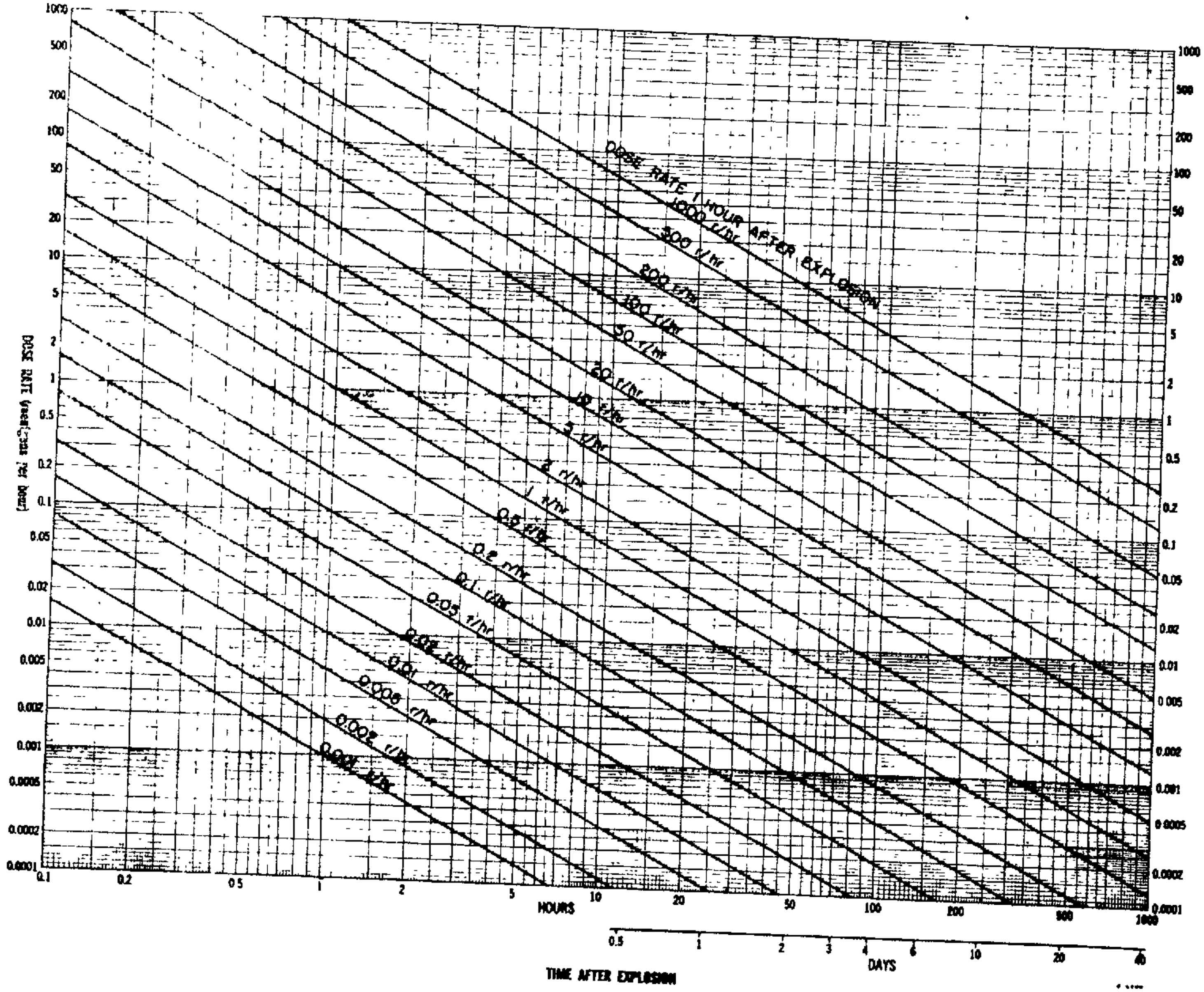

Figure 8. Chart for estimation of dose rates at various times after an atomic explosion.

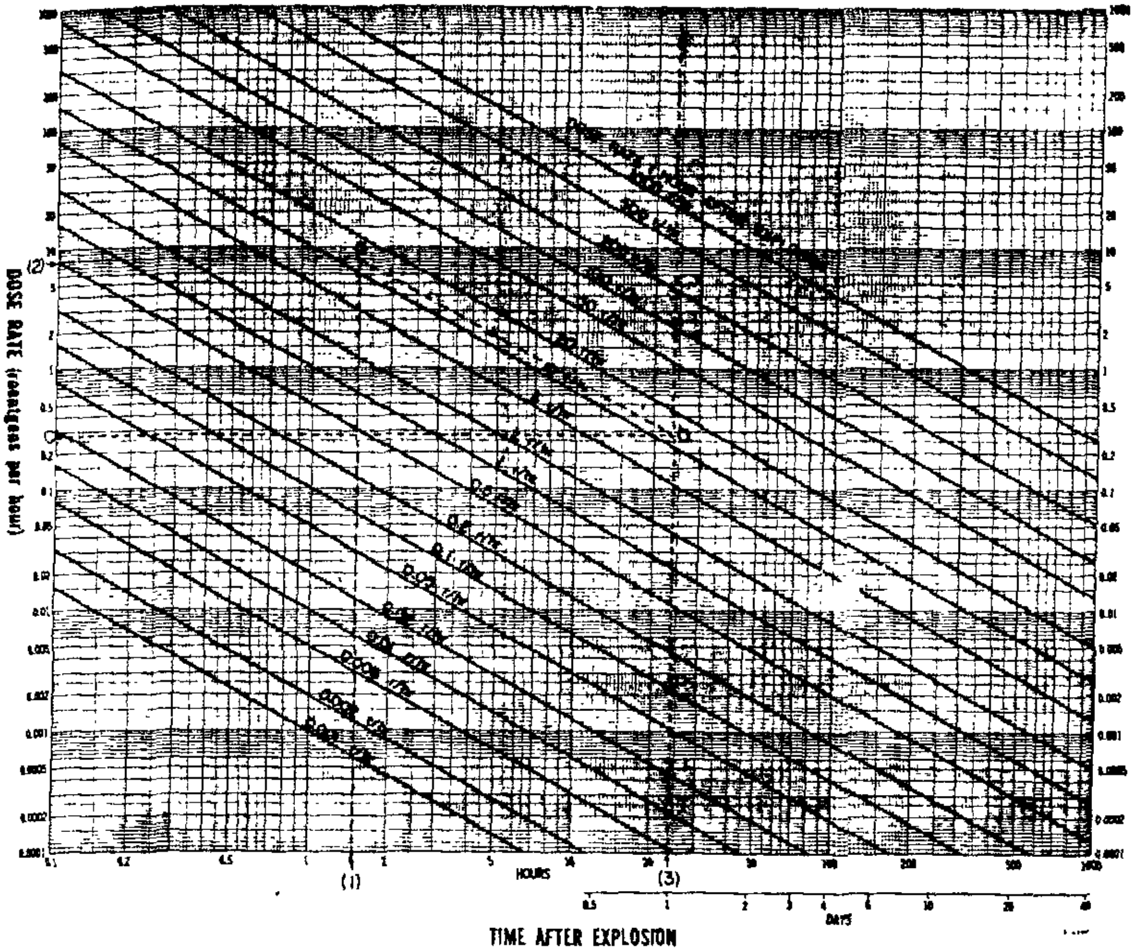

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Figure 8—Continued.

of "260 roentgens per hour." These establish a point *a*, representing the information given. As in the preceding example, a line through *a*, parallel to those on the chart, gives the variation of the radiation dose with time. Follow this line from *a* to *b*, where it meets the horizontal line for a dose rate of "1 roentgen per hour," indicated by arrow (3). The time represented by point *b* is then the time after the explosion at which the dose rate is 1 roentgen per hour. To find this time, follow the vertical line from *b* to *c*; the result, indicated by the point *c* is seen to be 52 hours after the explosion.

23. Effects of Acute Radiation Dosages

In considering the injurious effects of external gamma radiation on the body, it is necessary to distinguish between an *acute exposure* (short duration) and a *chronic exposure* (extends over considerable time). The most important consequence of acute radiation exposure is "radiation sickness," which is the result of penetrating nuclear radiation over a *large area of the body* in a short time. Under these conditions the symptoms and severity of the disease depend on the actual dosage. In section III the effects radii for gamma radiation were premised on a whole-body acute dose of 650 roentgens, which may be expected to produce nausea and vomiting of all personnel within 4 hours and to require their evacuation on the first day. In section VI, the threshold effects radii for troop safety (fig. 30) were premised on no decrease in combat effectiveness. The most obvious consequence of acute radiation exposure, as far as military personnel are concerned, is vomiting. In general, it may be assumed that those who do not vomit on the first day have not received a serious dose of radiation. For high radiation dosages (600 roentgens or more), symptoms first appear within 1 or 2 hours, but there may be a

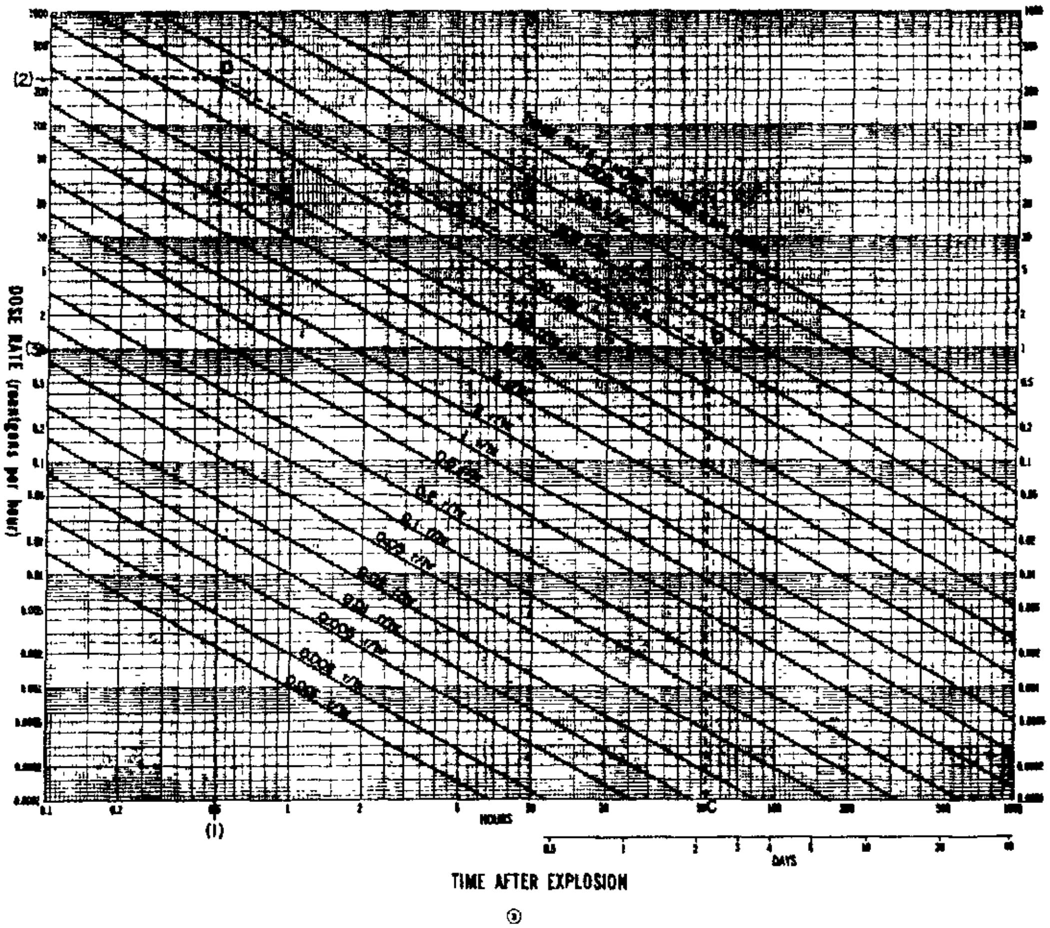

Figure 8. Chart for estimation of dose rates at various times after an atomic explosion—Continued.

latent period lasting up to several days. During the latent period, there is no apparent sickness. The occurrence of the latent period is significant militarily because it means that a person exposed to immediate nuclear radiation may not be incapacitated. An acute dosage of 50 roentgens or less will yield no symptoms of sickness and will result in no decrease in combat effectiveness. An acute dosage of 100 roentgens will produce nausea and vomiting in about 2 percent of personnel but none will require evacuation and all will be able to perform duty.

24. Chronic Dosage—Residual Radiation

The dose rate at which radiation is received by the body is an essential factor in determining the harm that may be done. Consequently, dosages which would be harmful if received in a short time often are not harmful if received over a long period. If the chronic dose rate is not too high, partial recovery can begin even while the body is exposed to nuclear radiation. *For example*: an acute dose of 200 roentgens would result in vomiting and nausea in about 50 percent of exposed personnel. On the other hand, a series of 8 exposures at weekly (or longer) intervals of 25 roentgens each would be expected to have no effect on combat ability. The probable effects of a series of chronic exposures upon successive days are indicated in the following tabulation in terms of the equivalent acute dose.

Daily chronic dose (roentgens)	Days exposure	Acute total dose (roentgens)	Actual dose equivalent (roentgens)
60	6	360	200
30	5	150	100
30	14	420	200
15	12	180	100
15	32	480	200

Figure 9. Probable effects of chronic whole-body gamma radiation doses.

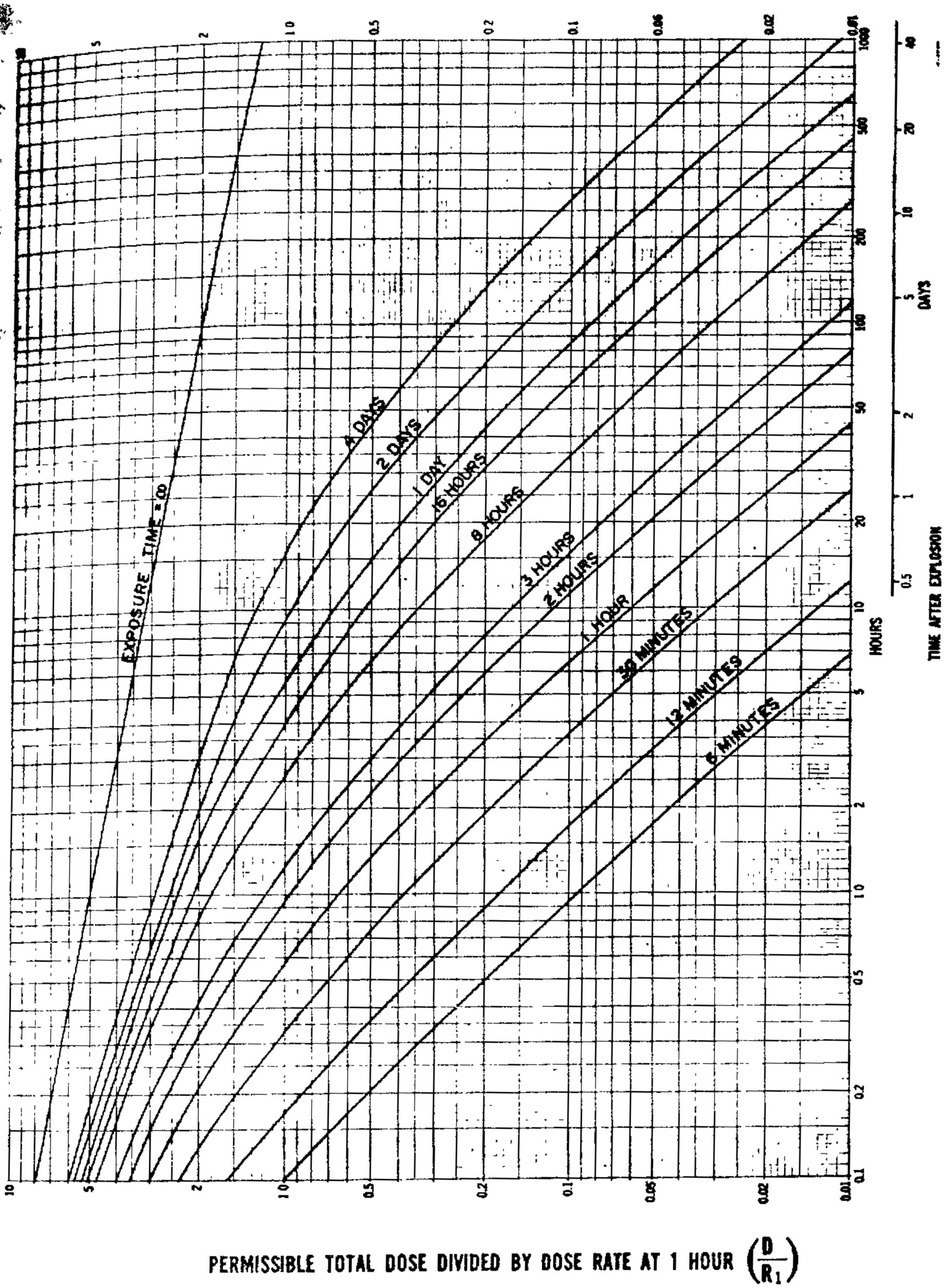

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Figure 10. Chart for estimation of allowable stay times in contaminated areas (based on dose rate at 1 hour after burst).

25. Allowable Stay-Times

a. General. In military operations it may become necessary for personnel to carry out assigned tasks in a contaminated area. Since the commander must take into consideration the radiation exposure as a factor in determining the present and probable future effectiveness of his men, he must determine which operations, if any, should be conducted in the contaminated area, and must impose an allowable "stay-time" on personnel working in the contaminated area. The allowable stay-time must be based on the dosage rate in the area, the decay rate of fission products, and a command determination of the total dose which he will permit personnel to be exposed to. The *immediate fighting effectiveness* of individuals who receive 100 roentgens (or less) within a period of 12 hours will, in general, not be reduced; but some casualties are liable to result if larger doses are received.

b. Based on Dose Rate 1 Hour After Burst. Figure 10, "Chart for estimating allowable stay-times in contaminated areas (based on dose rate at 1 hour after burst)," enables determination of allowable stay-times based on the known decay rate of fission products from an atomic burst. This figure is suitable for planning purposes only and is not applicable where the attack has been made by *radiological warfare agents*. (In the examples, which follow, of the use of this figure, the division $\frac{D}{R}$ may be performed through the use of fig. 15.)

(1) *First example in use of figure 10.* The radiation intensity in a contaminated area is 70 roentgens per hour at 30 minutes after an atomic explosion. An operation to be performed in this area is estimated to require 4 hours, and the total radiation dosage which personnel will be allowed to accept is 25 roentgens. How long after the explosion will it be necessary to wait before starting the operation?

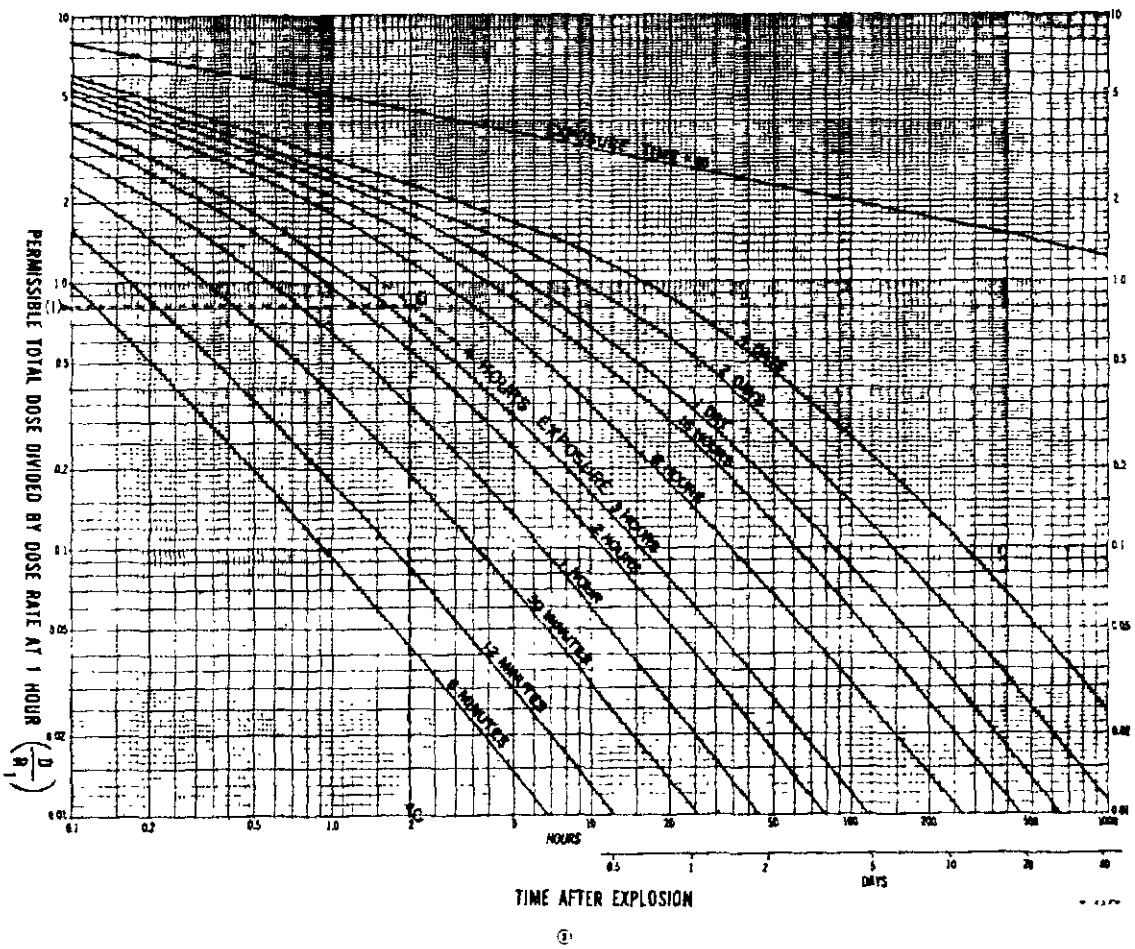

Figure 10. Chart for estimation of allowable stay times in contaminated areas (based on dose rate at 1 hour after burst)—Con.

The first step is to determine R_1, the dose rate at 1 hour after the explosion, corresponding to 70 roentgens per hour at 30 minutes after. This is done by the method described in paragraph 22*a*. In the present case, R_1 is found to be 30 roentgens per hour. Since D, the permissible total dose, is set at 25 roentgens, the value of $\frac{D}{R_1}$ is $\frac{25}{30}=0.83$. Now follow the horizontal line on the reproduction of figure 10 below for $\frac{D}{R_1}=0.83$, as indicated by arrow (1), until it meets the curve for "4 hours exposure" at the point *a*. Since this curve is not one of those on the chart, it is interpolated, as shown; this can be done with sufficient accuracy. The time of starting the operation in the contaminated area is then given by the reading on the horizontal scale corresponding to the point *a*. By drawing the vertical line from *a* to *c*, the required time is seen to be 2 hours after the explosion.

(2) *Second example of use of figure 10.* The radiation intensity in a contaminated area is 70 roentgens per hour at 30 minutes after an atomic explosion. An operation is commenced at 2½ hours after the explosion and personnel stay for 1 hour. What radiation dosage will they have received in this time?

It is necessary to know R_1 (the dose rate at 1 hour after detonation), but this need not be determined as the first step. However, in this case, since the initial data are the same as in the preceding example, R_1 is known to be 30 roentgens per hour. To solve the problem find the vertical line, on the reproduction of figure 10 below marked by arrow (1), representing "2½ hours" after the explosion. Follow this up until it meets the curve for "1 hour" exposure time, indicated by the arrow (2) at the point *a*. The value of $\frac{D}{R_1}$ at this point is obtained from the vertical scale by following from *a* to *c*; the result is seen to be 0.27. Consequently, since $\frac{D}{R_1}$ is 0.27 and R_1 is 30, the dose received will be $30\times0.27=8.1$ roentgens.

c. Based on Dose Rate at Time of Entry into Contaminated Area. For convenience, figure 11, "Chart for estimation of allowable stay-times in contaminated areas (based on dose rate at time of entry)," is included. The general technique of its use is similar to that for figure 10. Two illustrative examples of its application follow.

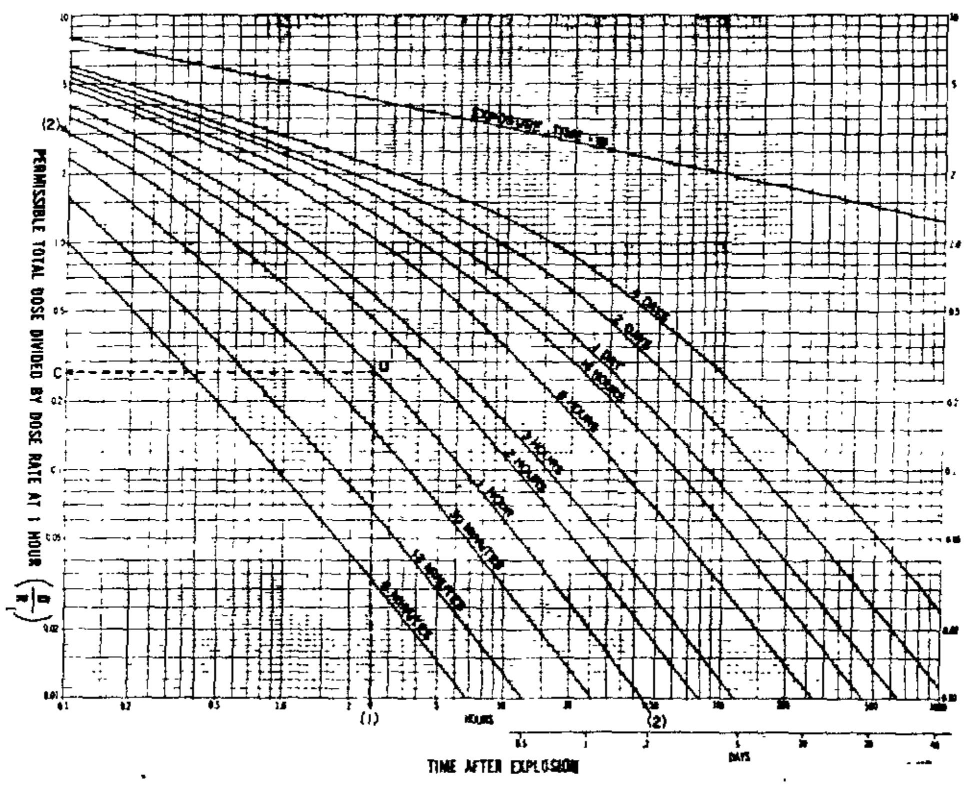

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Figure 10—Continued.

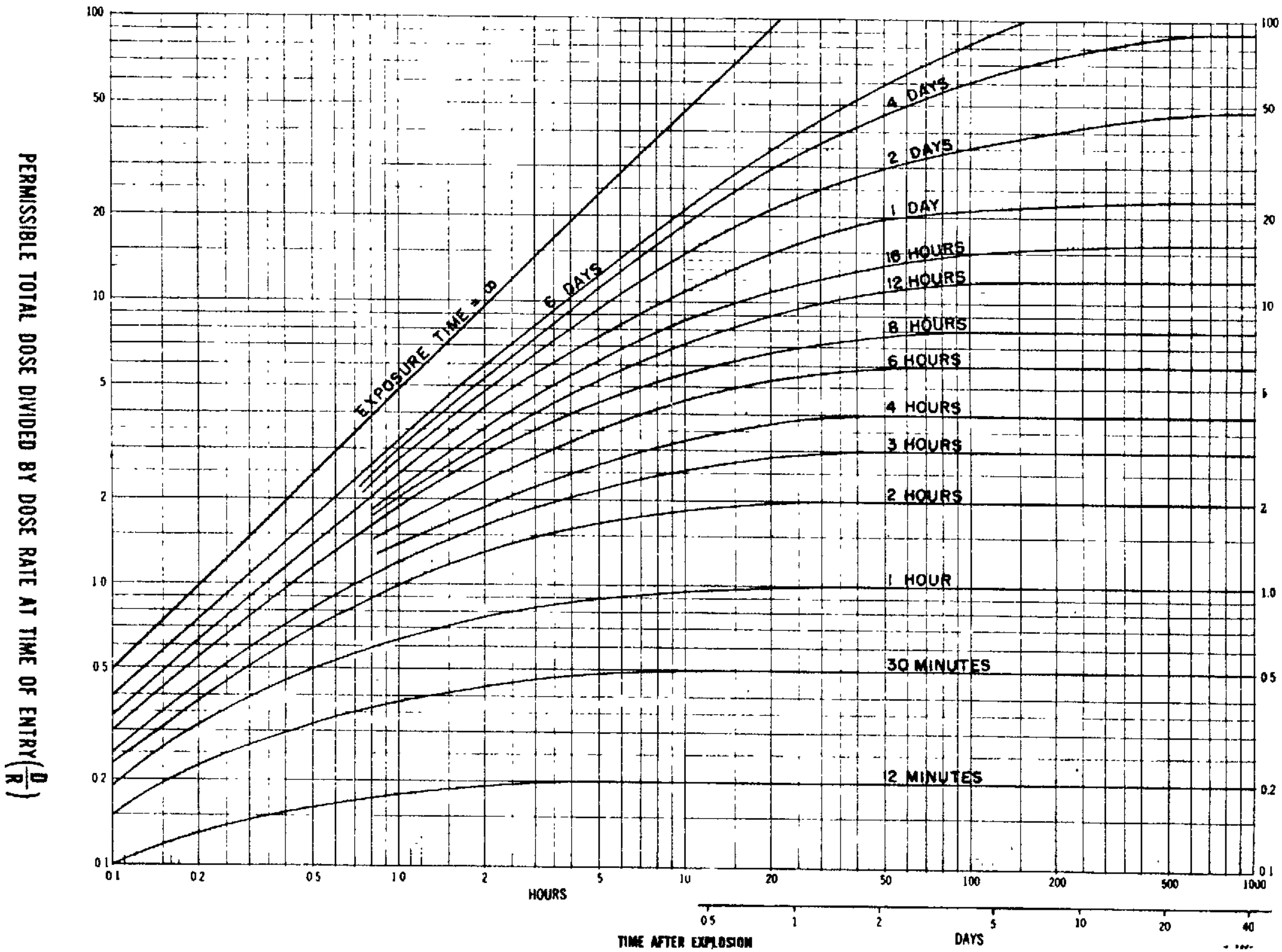

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Figure 11 Chart for estimation of allowable stay times in contaminated areas (based on dose rate at time of entry).

(1) *First example of use of figure 11.* Upon entering a contaminated area at 4 hours after an atomic explosion, the dose rate R was observed to be 15 roentgens per hour. If the permissible dose (D) is 25 roentgens, what will be the allowable stay (or exposure) time?

The value of $\frac{D}{R}$ is $\frac{25}{15}=1.66$. Find the horizontal line in the reproduction of figure 11 below for "$\frac{D}{R}=1.66$," marked by arrow (1), and follow this until it meets the vertical line, indicated by arrow (2), for "4 hours" after the explosion, at the point a. This point is seen to fall just above the curve marked "2 hours" of exposure time. The allowable stay-time will be slightly *more than* 2 hours.

(2) *Second example of use of figure 11.* Upon entering a contaminated area at 12 hours after an atomic explosion, the radiation intensity (R) was found to be 5 roentgens per hour. If an operation requiring 2½ hours was then started, what would be the dose (D) received by personnel?

Follow the vertical line in the reproduction of figure 11 below for "12 hours" after the explosion, indicated by arrow (1), until it meets the curve for "2½ hours" exposure time. This curve is not one of those on the original figure, but its position may be estimated with sufficient accuracy by interpolation between "2 hours" and "3 hours," as shown by arrow (2). The value of $\frac{D}{R}$ at the point *a* where the vertical line and the exposure time curve meet is obtained by following the horizontal line from *a* to *c*. Thus, $\frac{D}{R}$ is found to be 2.3. Since R is given as 5 roentgens per hour, D is $2.3\times5=11.5$ roentgens, and this will be the dose received.

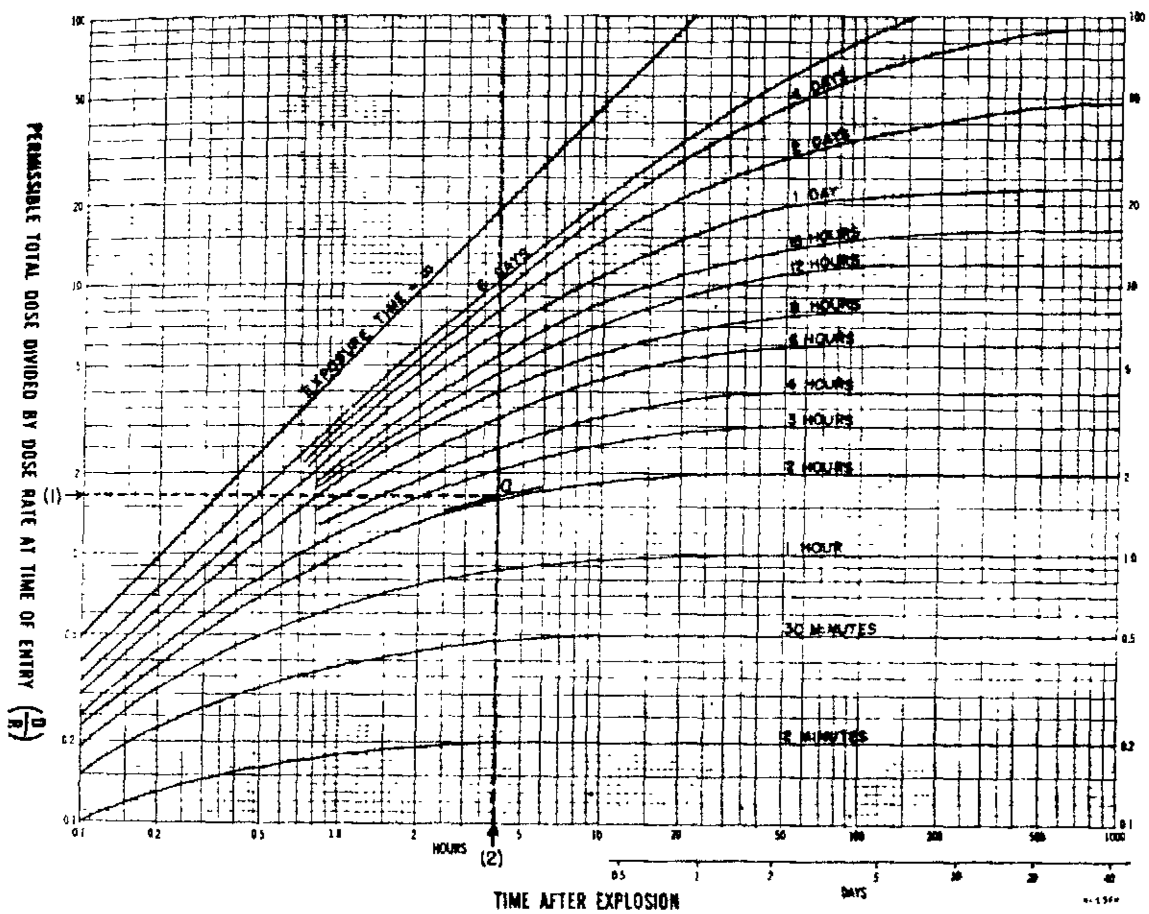

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Figure 11—Continued.

d. Action Required if Stay-Time is too Short. If the stay-time is too short to accomplish the desired mission the commander must either—

(1) Revise his allowable dose upward, or

(2) Use personnel in shifts, or

(3) Wait for radioactive decay to lower the radiation intensity in the area, thus permitting a longer stay-time. This is particularly applicable to less urgent tasks.

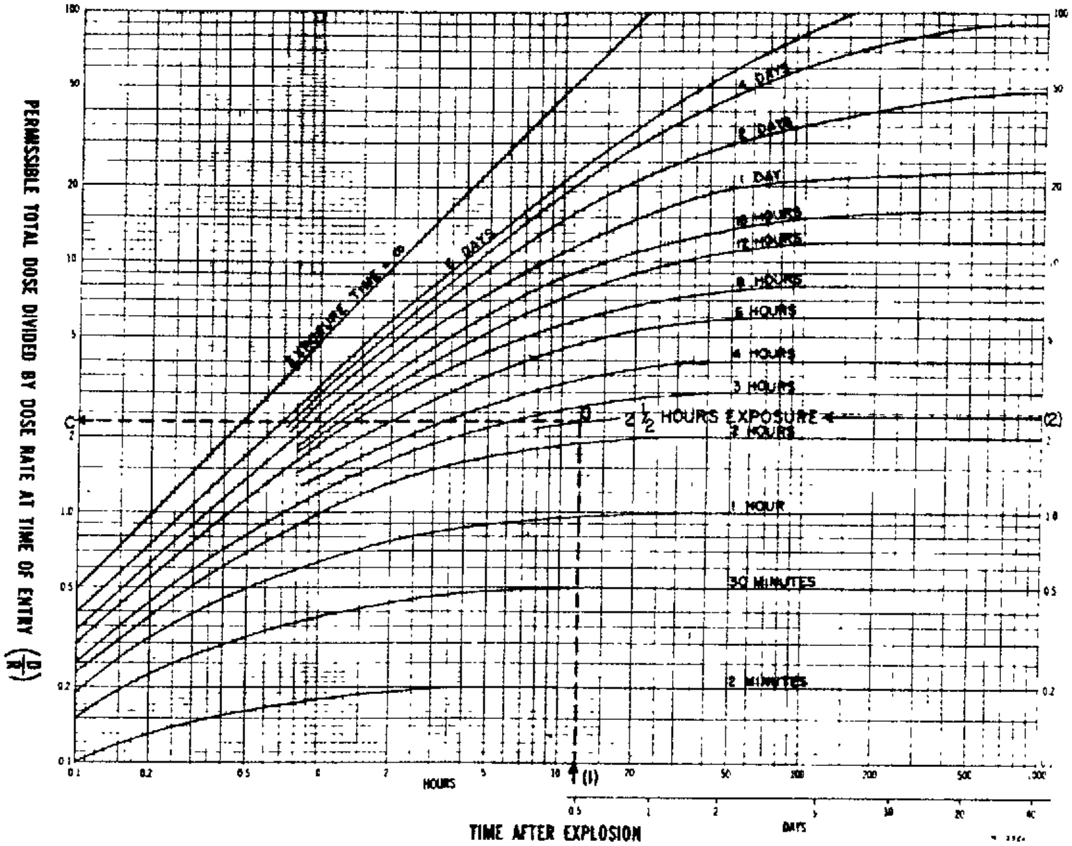


Figure 11. Chart for estimation of allowable stay times in contaminated areas (based on dose rate at time of entry).—Con

Section V. CASUALTY AND DAMAGE ESTIMATION

26. General

When an atomic weapon is detonated over a given target it may be expected, except for unduly high bursts, that there will be a zone (extending radially from ground zero) in which there will be almost certain damage to the target. It may also be expected that, outside of the certain-damage zone, there will be a zone of probable damage in which the actual level of damage imposed will vary with distance from ground zero from virtually complete damage to virtually no damage. It may also be expected that, outside of the zone of probable damage, there will be a zone of no damage. It cannot, of course, be expected that the lines of demarcation between these zones will be capable of precise definition. It can be expected, however, that these zones will usually exist. It hence is possible to determine the distance from ground zero at which the probability of damage is that desired or required. In doing this it is convenient to work with that distance at which the probability of damage is 0.5.

Note.—Probabilities are usually expressed as a decimal, 1.0 being considered as certain. A probability of 0.5 is thus the same as a 50-percent probability.

All effects radii tabulated in figures 2 through 4 have been correlated with the 50-percent probability point. This is illustrated in figure 12. In referring to damage this pamphlet, as previously explained (par. 13) refers to "severe" damage. Thus, a "probability of damage," as used herein, is to be interpreted as a "probability of severe damage." Likewise, a "probability of no damage" is to be interpreted as a "probability of no severe damage."

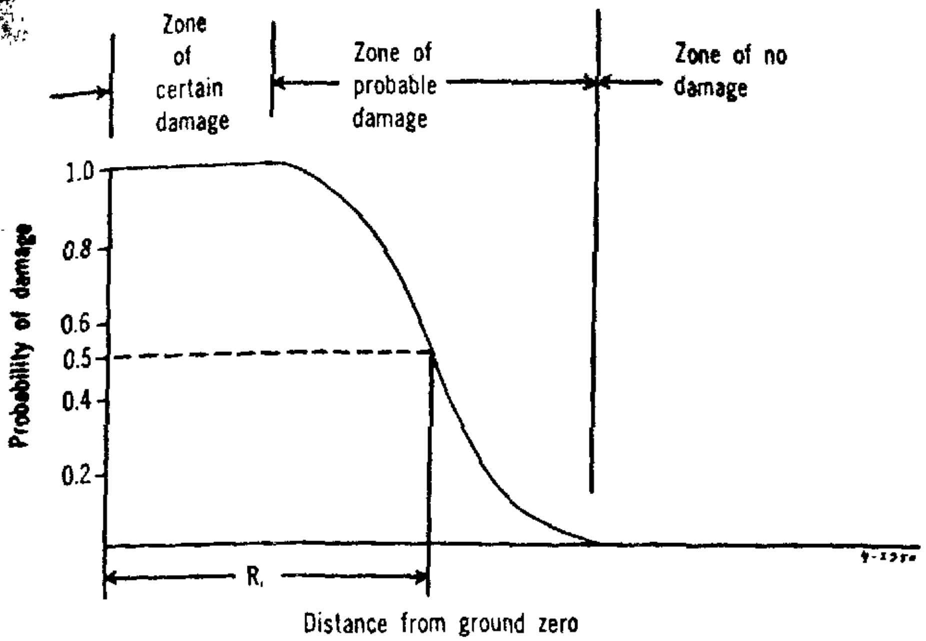


Figure 12. Probability of damage versus distance from ground zero.

The relationship between probability of damage and distance from ground zero, as it exists for a given set of conditions, is known as the damage function applicable to that set of conditions. As conditions vary, e. g., different targets, different effects, different burst conditions, it may be expected that the damage function will change. These changes will evidence themselves in the relative size of the zones of certain damage and of probable damage. Sometimes the zone of probable damage will be relatively very large, and other times it will be relatively very small. A special weapons adviser making a target analysis will choose the specific damage function which test results have shown to be applicable to the set of conditions by which he is governed. This he does by selecting the proper so-called "variability." The larger the variability, the larger the relative size of the zone of probable damage. The proper variability to use depends upon the variation in target response expected from the type of effect being utilized. This text, for simplicity, assumes a constant 20-percent variability for all types of targets. This is substantially equivalent to saying that the extent of the zone of probable damage is assumed as always being about two times the extent of the zone of certain damage. Figure 12 illustrates a damage function for which the variability is 20 percent.

27. Effect of Probable Delivery Error

No delivery system is capable of delivery without error in all cases (par. 12). The probable delivery error must, therefore, be taken into account in determining the probable variation of the actual ground zero from the planned, or recommended, ground zero. This is important in planning the utilization of weapons whose effects cover large areas.

28. Point Targets—Non-Zero CEP

The probability (P) that (severe) damage will be imposed on a point target by a planned atomic detonation is dependent on: the effects radius (for severe damage) of the weapon being detonated (R_e) against the type of target in question; the location of the point target with respect to the recommended ground zero (d = distance from RGZ), the probable delivery error (CEP) assumed circular throughout this text; and the variability applicable to the conditions present—assumed 20 percent throughout this text.

Figure 13, "Probability of damage to point targets—20-percent variability," expresses the relationship between these basic factors for 20-percent variability (fig. 13). It is applicable to the determination of probability of damage to a point target whose location with respect to the recommended (intended) ground zero is known, when

the delivery system CEP and weapon effects radius (R_e) are also known. It is also applicable to the determination of the R_e required for a stipulated probability of damage.

a. Examples of Use of Figure 13.

(1) *Given* A point target 5,000 feet from RGZ.
CEP = 1,000 feet
R_e = 8,000 feet
Find. Probability of damaging the target.
Solution: $\frac{d}{CEP}=5$

$\frac{R_e}{CEP}=8$

Probability (P) of damaging target = 0.94 or 94 percent.

(2) *Given.* A point target at RGZ.
CEP = 1,000 yards
R_e = 400 yards
Find: Probability of damaging target.
Solution. $\frac{d}{CEP}=0$

$\frac{R_e}{CEP}=0.4$

P = 0.11

(3) *Given:* A tank park, considered as a point target, located at RGZ.
Find: Probability of damaging target with a CHARLIE (20-KT) weapon detonated at low air-burst height and delivered by toss bombing.
Solution: R_e = 190 yards (from fig 2)
CEP = 500 yards (from fig. 1)

$\frac{R_e}{CEP}=0.38$; $\frac{d}{CEP}=0$

P = 0.10

(4) *Given:* A point target 5,000 feet from RGZ
CEP = 1,000 feet
Desired: A 90-percent probability of damage.
Find: Required R_e.
Solution $\frac{d}{CEP}=5$

Enter figure 13 at $\frac{d}{CEP}=5$, intersect P = 0 9.

read $\frac{R_e}{CEP}=7.15$

Required R_e = 7.15 (1,000) = 7,150 feet.

b. Extension Chart for Figure 13. It will be noted that the maximum $\frac{d}{CEP}$ for which figure 13 is applicable is 7.5, and that the maximum $\frac{R_e}{CEP}$ for which figure 13 is applicable is 10.0. In the event that $\frac{d}{CEP}$ exceeds 7.5, or in the event that $\frac{R_e}{CEP}$ exceeds 10, figure 14, "Extension chart for figure 13," is applicable in determining the probability of damage. In making this determination it is possible to neglect CEP, without sacrifice of accuracy, because of the relative magnitudes of d and CEP, and R_e and CEP. *For example:*

Given d = 10,000 yards
CEP = 1,000 yards
R_e = 10,000 yards
Find Probability of damage
Solution $\frac{d}{CEP}>7.5$, therefore use figure 14

$\frac{d}{R_e}=1.0$

P = 0.5 (from fig. 14)

c. Alignment Chart for Multiplication and Division. To facilitate multiplication and division in determining the ratios $\frac{d}{CEP}$, $\frac{R_e}{CEP}$, etc., figure 15 may be used. *For example:* if CEP = 400 (use scale A), if d = 1,000 (use scale B), then by figure 15, $\frac{d}{CEP}=2.5$ as illustrated on scale C of figure 15. Conversely, if $\frac{d}{CEP}=2.5$, if CEP = 400, then d = 1,000. Any straight line intersecting all three scales of figure 15 will intersect these scales at correct values for the parameters designated for scale A, scale B, and scale C in the table of figure 15 which indicates the "Intended application of chart."

29. Point Targets—Zero CEP

There are three instances in which zero CEP is appropriate: when the artillery delivery system is used for the BAKER and CHARLIE weapons (fig. 1); when the actual ground zero is known from poststrike data; and when the CHARLIE weapon is prepositioned In all three of these instances figure 14, "Extension chart for figure 13," is directly applicable to determine the probability of damage to a point target, or conversely to determine the required R_e to effect a stipulated probability of damage

a. Examples of Finding Probability of Damage

(1) *Given* A point target, at ground zero, consisting of troops in the open Weather is clear
Find Probability of severe damage to target from thermal effects of CHARLIE weapon delivered at low air-burst height by artillery.
Solution R_e = 2,105 (from fig. 3, visibility = 20)
CEP = 0 (from fig 1)
d = 0 (given)

$\frac{d}{R_e}=0$

P = over 99 99 percent (from fig 14)

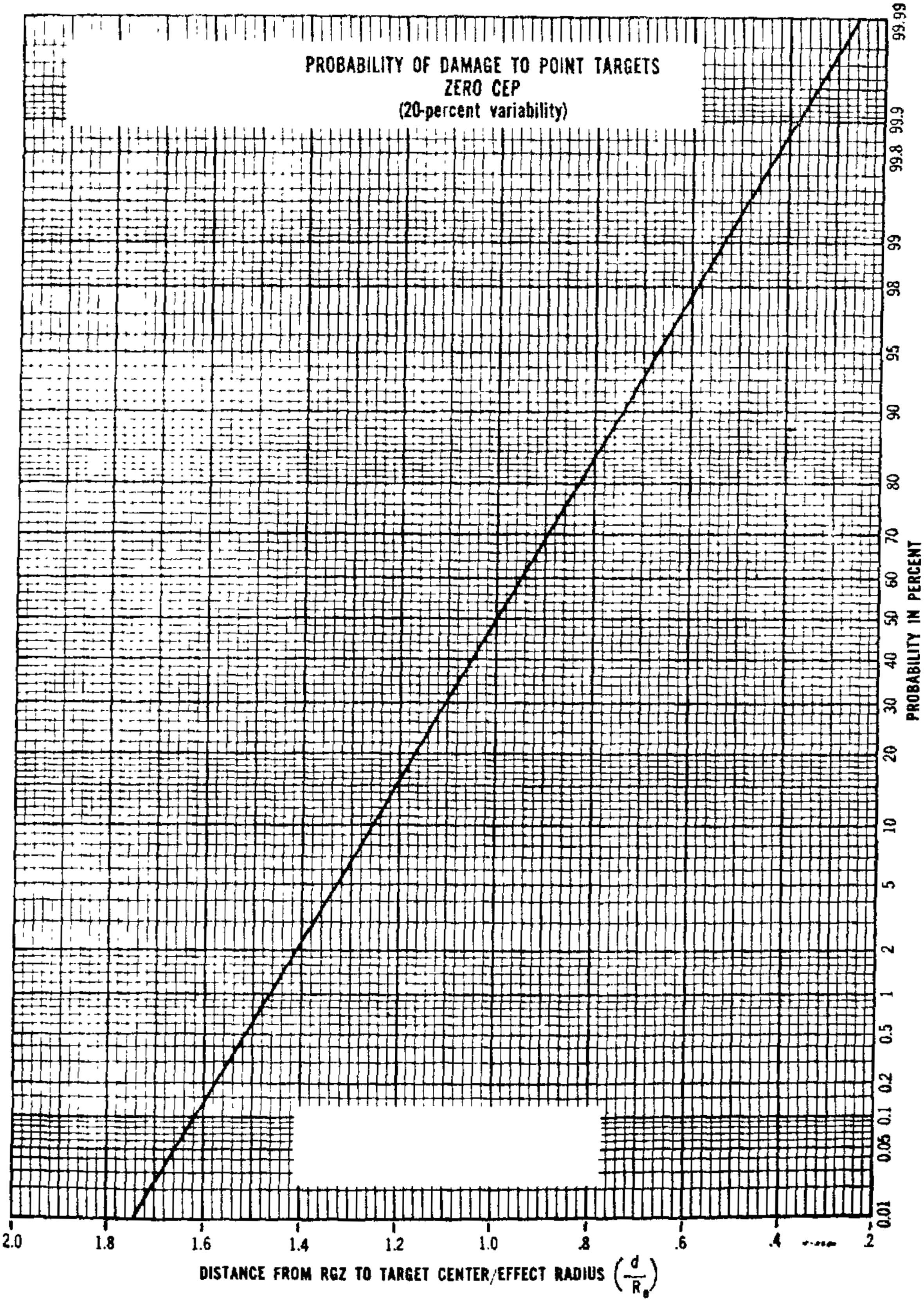


Figure 14. Extension chart for figure 15.

1. CHART ENABLES MULTIPLICATION OF TWO NUMBERS OR DIVISION OF TWO NUMBERS

a. MULTIPLICATION. IN MULTIPLYING TWO NUMBERS PLACE ONE ON SCALE A AND THE OTHER ON SCALE C, READ PRODUCT ON SCALE B. EXAMPLE: 2.5 (SCALE C) MULTIPLIED BY 400 (SCALE A) = 1000 (SCALE B)

b. DIVISION. IN DIVIDING TWO NUMBERS PLACE THE DIVIDEND ON SCALE B AND THE DIVISOR ON SCALE A, READ QUOTIENT ON SCALE C. EXAMPLE: 1000 (SCALE B) DIVIDED BY 400 (SCALE A) = 2.5 (SCALE C)

INTENDED APPLICATION OF CHART		
SCALE A	SCALE B	SCALE C
CEP	d	d/CEP
CEP	R_e	R_e/CEP
R_t	R_e	R_e/R_t
R_t	CEP	CEP/R_t
R_e	d	d/R_e
CEP	R_t	R_t/CEP
CEP	d_b	d_b, CEP
R	D	D/R

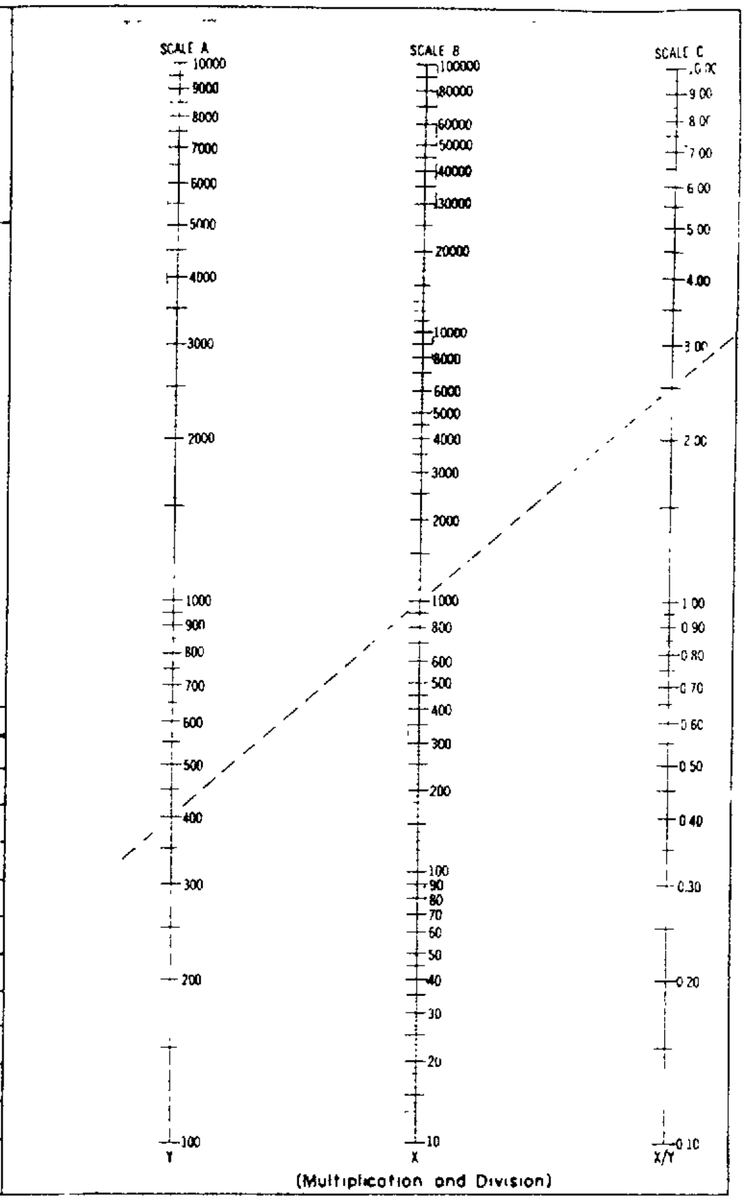


Figure 15. Alignment chart for multiplication and division

(2) *Given:* A point target, consisting of personnel in the open, 700 yards from ground zero. Visibility 20 miles.

Find: Probability of damage to target from thermal effects of CHARLIE weapon delivered at low air-burst height by artillery.

Solution: d = 700

R_e = 2,105

$\frac{d}{R_e}$ = 0.33 (from fig. 15)

P = over 99.96 percent.

b. Examples of Finding Required R_e.

(1) *Given:* A point target, 500 yards from ground zero, consisting of troops in heavy bunkers.

Find: Required R_e to effect an 80-percent probability of severe damage by gamma radiation from an artillery-delivered weapon.

Solution: P = 0.8

$\frac{d}{CEP}$ is infinite; therefore figure 14 is applicable.

$\frac{d}{R_e}$ = 0.83 (from fig. 14)

Required $R_e = \frac{500}{0.83}$ = 602 yards (from fig. 15)

Note: Figure 4 indicates that the BAKER weapon, at low air burst would be a satisfactory weapon to effect the required damage.

Given. A point target, 200 yards from ground zero, consisting of a supply point.

Find Smallest available artillery-delivered weapon which will effect a probability of severe damage of 0.75.

Solution $\frac{d}{R_e}=0.87$ (from fig. 14)

$d=200$ yards

Required $R_e=\frac{d}{0.87}=230$ yards

The BAKER weapon will more than suffice (fig. 2; BAKER $R_e=545$ yards).

Area-Target Considerations

a. *General.* The determination of damage occurring to (or being imposed on) an area target is more complex than for a point target. In the case of the point target, since the target either will or will not be (severely) damaged, there are but two pertinent probabilities—the probability of (severe) damage and the probability of no (severe) damage. In the case of area targets, however, the target either will be (severely) damaged, will be partially (severely) damaged, or will not be (severely) damaged. Hence, there is a probability associated with every *degree* of partial (severe) damage to the target as a whole, as well as a probability of complete (severe) damage and a probability of no (severe) damage.

b. *Target Shape.* Since atomic weapon effects are evidenced spherically about the point of detonation, they are evidenced circularly on the ground about ground zero. Consequently, target shape is important. For simplicity, this text limits its area-target considerations primarily to circular targets. Paragraph 37 covers the question of noncircular targets in terms of equivalent circular targets, and of irregular targets in terms of a system of points.

c. *Relationship Between Probability of Damage and the Amount of Damage.* It is reasonable to expect that the probability of 10-percent damage to a target will be greater than the probability of 90-percent damage, under the same conditions. The degree of partial damage to the target as a whole (i. e., to *all* target elements) is called "fractional damage." Hence, generalizing the foregoing statement: the probability of a large fractional damage will be less than the probability of a small fractional damage. This relationship can be illustrated by what is called the *P-f curve* for the circumstances at issue (P referring to probability of damage, and f referring to fractional damage). "Fractional damage" is not to be interpreted with respect to a *single* target element, but always with respect to *all* target elements. A typical P-f curve is illustrated in figure 16.

In figure 16 it can be seen that the probability of 0.6 damage (f=0.6) is 0.5 (P=0.5). Or, P(0.6)=0.5. Likewise, P(0.3)=0.8, and P(0.75)=0.2.

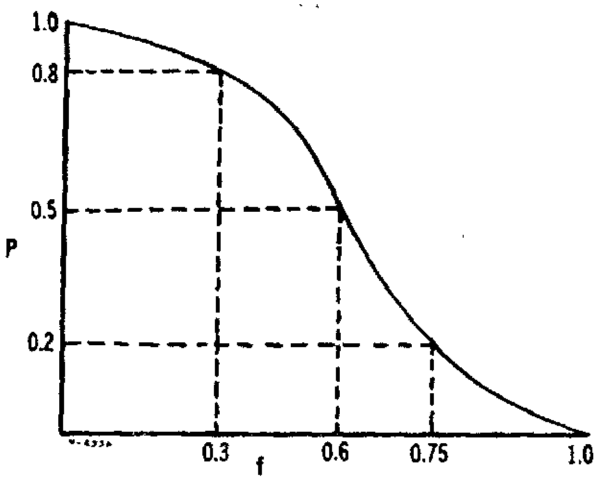
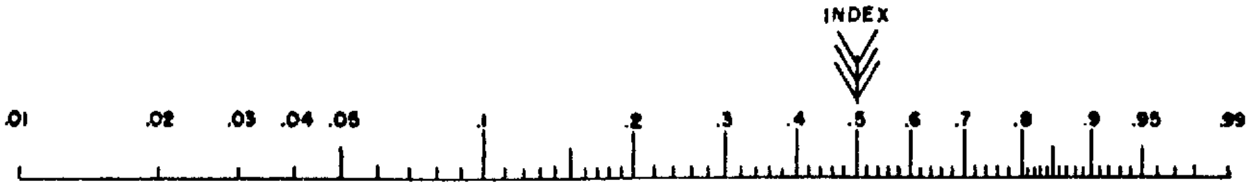


Figure 16. A typical P-f curve.

31. P-f Relationship for Circular Targets

Figure 17, "P(f) nomograph, 20-percent variability," has been designated to enable determination of the P-f relationship for circular targets of radius R_t, when attacked with a weapon of effects radius R_e, delivered with a circular probable error (CEP), *provided the recommended ground zero (RGZ) coincides with the target center.* Oftentimes we are not concerned with the entire P-f curve but rather with a specific point on it. *For example:* suppose it has been determined as necessary, and the commander has so directed, that a 40-percent fractional damage be imposed on a designated target and that there be a 90-percent assurance (probability) of attaining that damage. This nomograph, together with the probability scale associated therewith, enables determination of the required R_e to attain compliance with the commander's desires, provided the RGZ is designated at target center. The probability scale reproduced below is intended for use only with figure 17 and then only when a delivery error (CEP) is inherent in the delivery system used. For convenience it is recommended that the scale be traced on a piece of paper or acetate of appropriate size so that it may be placed directly on figure 17

PROBABILITY SCALE FOR P-f NOMOGRAPH



a. Example.

Given $R_t = 1{,}000$ yards
CEP = 500 yards
$R_e = 1{,}000$ yards
RGZ at target center

Find P(0.4); i. e., find the probability of attaining a 40-percent fractional damage.

Solution (By fig. 17.)

(1) $\frac{CEP}{R_t} = 0.5$

(2) $\frac{R_e}{R_t} = 1.0$

(3) Orient the probability scale on the nomograph in exactly the same orientation as the probability scale printed at the top of the nomograph, and so place it on the nomograph that the index rests at $\frac{CEP}{R_t} = 0.5$ and $\frac{R_e}{R_t} = 1.0$

(4) Read P = 0.94 at point on probability scale where curve for fractional damage f = 0.4 crosses probability scale

(5) P(0.4) = 0.94.

Note (1) All of the following probabilities obtain in this instance, as determined directly from the probability scale

f	P
0.01	0.99+
0.05	0.99+
0.10	0.99+
0.20	0.99+
0.30	0.98
0.40	0.94
0.50	0.85
0.60	0.70
0.70	0.46
0.80	0.17
0.90	Less than 0.05
0.99	Less than 0.01

(2) The complete P-f curve can then be plotted:

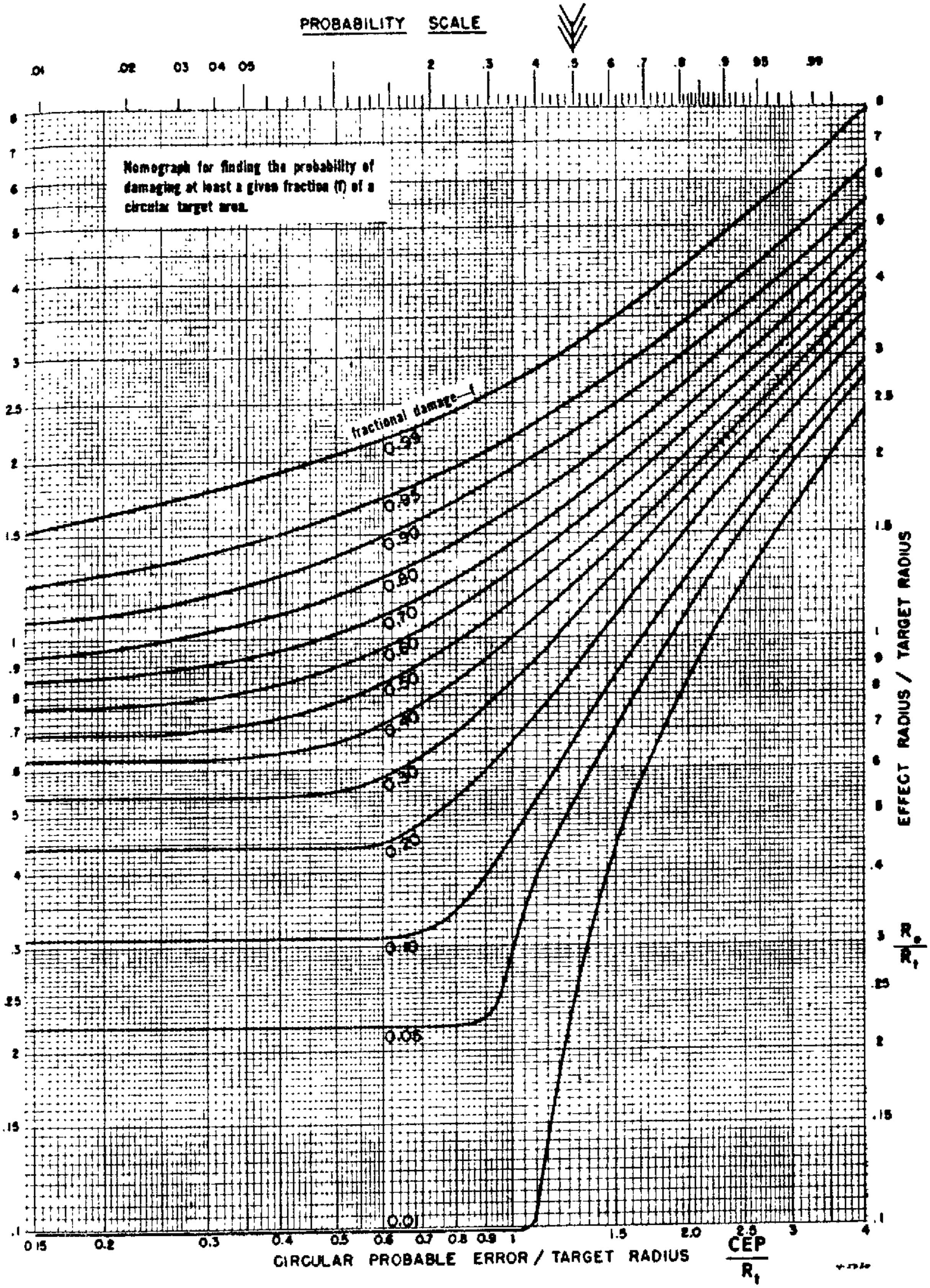
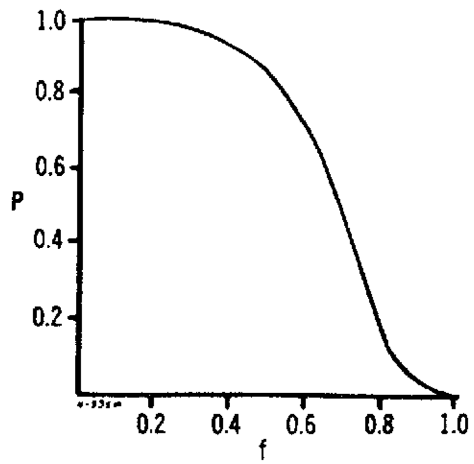


Figure 17. P(f) nomograph 20 percent variability.



b. Example.

Given: $R_t = 1{,}000$ yards
$CEP = 500$ yards
RGZ at target center

Desired $P(0.4) = 0.8$

Find: Required R_e

Solution: (1) Determine $\frac{CEP}{R_t} = 0.5$

(2) Properly orient the probability scale and place it on the nomograph, with the index on the line $\frac{CEP}{R_t} = 0.5$.

(3) Keeping the probability scale horizontal, and keeping the index on the line $\frac{CEP}{R_t} = 0.5$, move the probability scale until the curve for fractional damage $f = 0.4$ crosses the probability scale at $P = 0.8$

(4) Read the value of the $\frac{R_e}{R_t}$ line where the probability scale was stopped in step (3)

This value is $\frac{R_e}{R_t} = 0.82$.

(5) If $\frac{R_e}{R_t} = 0.82$

then $\frac{R_e}{1{,}000} = 0.82$

and the required $R_e = 820$ yards.

Note The ABLE weapon at high air-burst height ($R_e = 825$ for blast damage) will satisfy this requirement against built-up areas (Fig. 2.)

c. RGZ Not at Target Center. Figure 17 and its associated probability scale are not applicable when the RGZ does not coincide with the target center. It is not possible to determine the P-f relationship for area targets with offset RGZ by the methods of this pamphlet. This is one of the restrictions in scope of application of these methods referred to in the foreword. (This omission is for simplification reasons.)

32. Concept of "Expected" Fractional Damage

a. General. The "expected" fractional damage ($\bar{f}$) is that damage which is to be anticipated "on the average." (This does not necessarily mean that the probability of its occurrence is 50 percent. The probability may be 50 percent, or it may be higher or lower depending on the circumstances present.) If a given atomic strike were repeated a very large number of times under identical circumstances, and if the resulting damage were then averaged for all these strikes, this average would be the expected fractional damage. This is what is meant by "on the average."

b. Relation of Expected Fractional Damage to the P-f Curve. It has been stated that the P-f curve sets forth the relationship between fractional damage ($\bar{f}$) and the probability (P) of its occurrence, to an area target, under a given set of circumstances. The expected fractional damage ($\bar{f}$) (or expected damage, for short) is a point on the P-f curve. It thus has an associated probability of occurrence P ($\bar{f}$) which is determined from the applicable P-f curve.

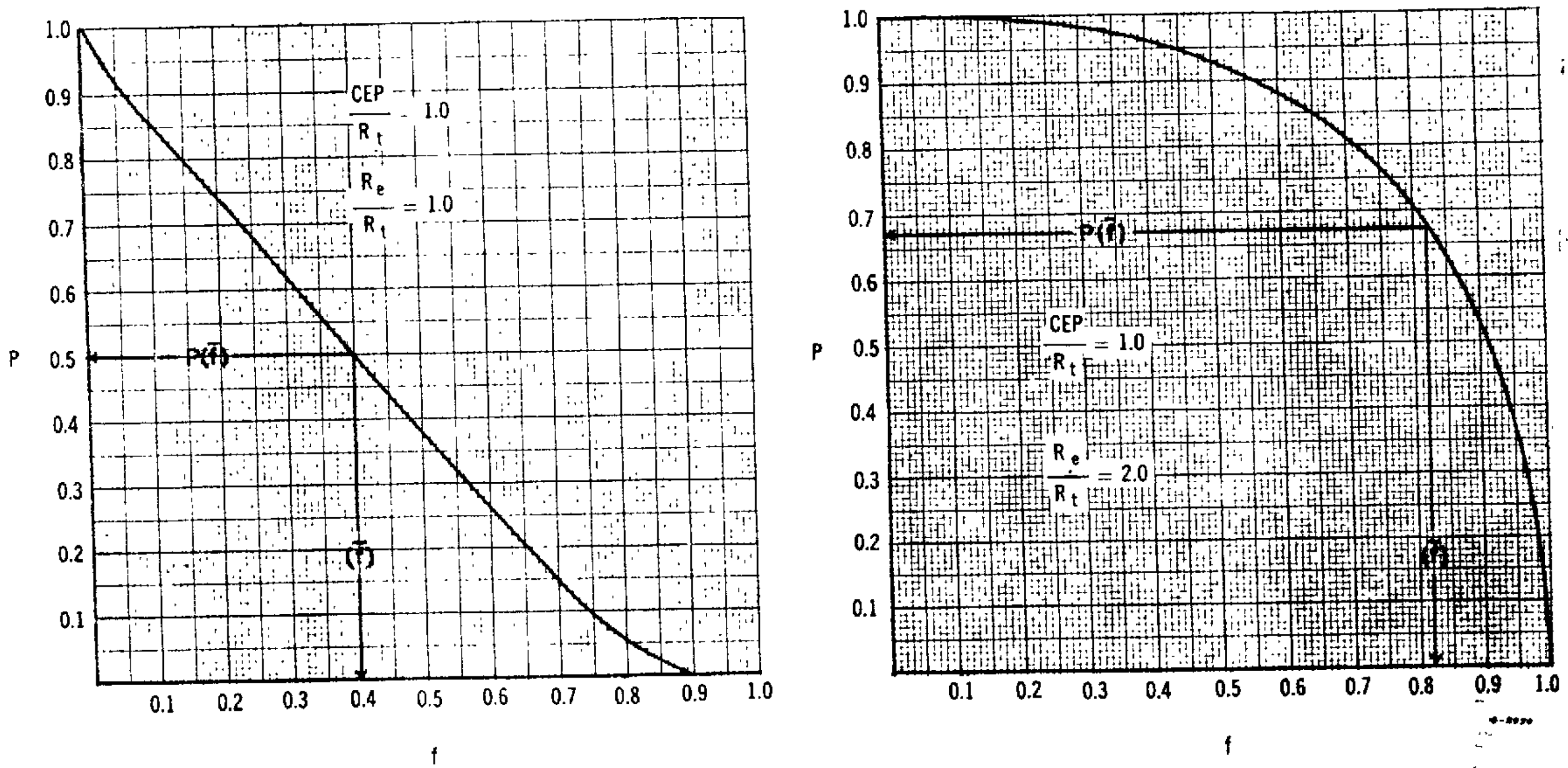
Figures 18 and 19 present typical P-f curves for five different weapon-target systems (as defined by R_t, R_e, and CEP) and indicate in each example the "expected" fractional damage together with the associated probability. The associated probability is as low as 32 percent and as high as 75 percent depending on the characteristics of the weapon-target system. The dominant characteristics of each of the weapon-target systems are as follows:

(1) *Example 1.* R_e, R_t, and CEP all equal, high probabilities for low damage fractions, low probabilities for high damage fractions, and median $\bar{f}$ and $P(\bar{f})$.

(2) *Example 2.* R_e greater than R_t and CEP; high probabilities for low damage fractions, median probabilities for high damage fractions, a high $\bar{f}$ and a relatively high $P(\bar{f})$. As between example 1 and 2, example 2 illustrates the effect of using a larger weapon.

(3) *Example 3.* CEP greater than R_e and R_t; high probability of missing target, low probabilities for all damage fractions, and a low $\bar{f}$ and $P(\bar{f})$. As between examples 1 and 3, example 3 illustrates the effect of a larger probable delivery error

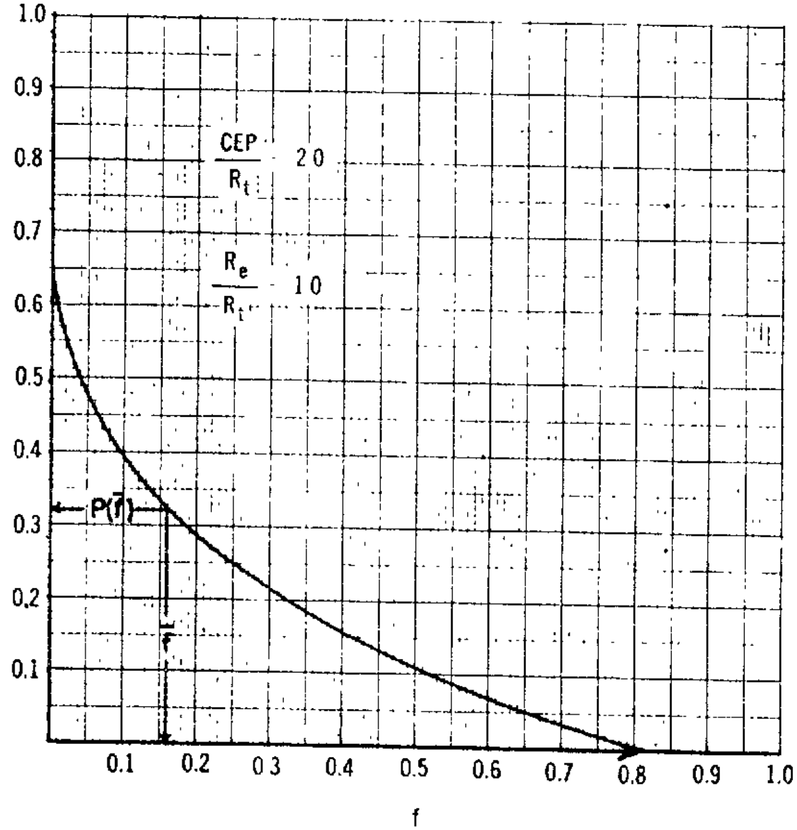
(4) *Example 4.* CEP and R_t greater than R_e: high damage fractions impossible to



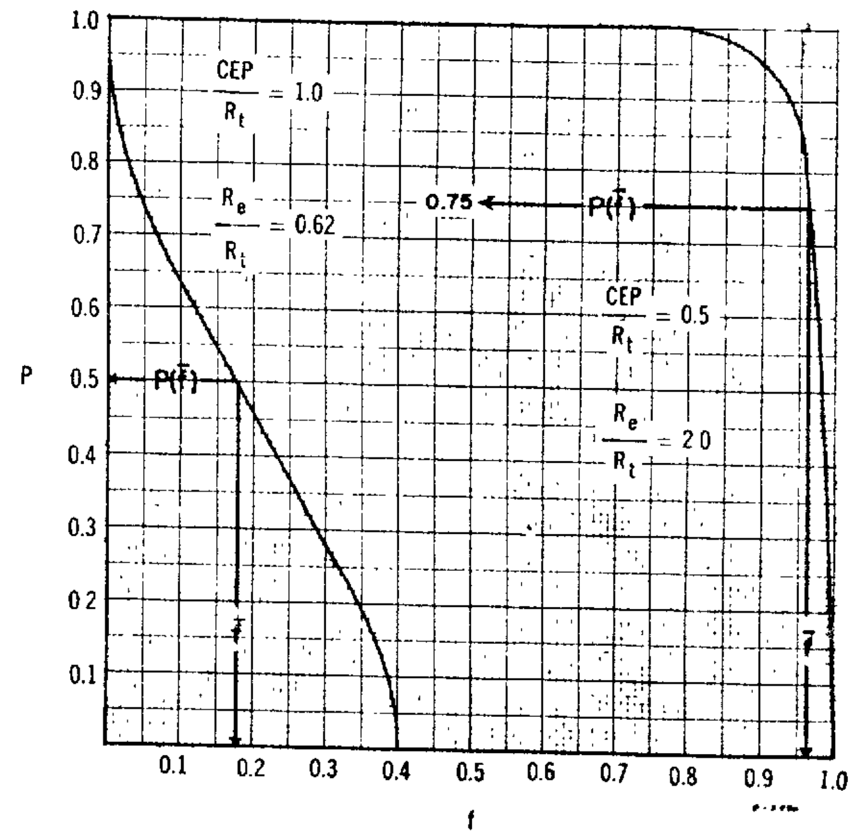
EXAMPLE 1

EXAMPLE 2

Figure 18. The relationship between probability of damage and expected fractional damage.



EXAMPLE 3



EXAMPLES 4 and 5

Figure 19. The relationship between probability of damage and expected fractional damage.

attain, a low $\bar{f}$ and a median $P(\bar{f})$. As between examples 1 and 4, example 4 illustrates the effect of using a smaller weapon.

(5) *Example 5.* R_e greater than R_t and CEP; very high probabilities for all except the very highest damage fractions, a very high $\bar{f}$ and a quite high $P(\bar{f})$. As between examples 2 and 5, example 5 illustrates the effect of using a more accurate delivery system. As between examples 1 and 5, example 5 illustrates the use of a much larger weapon and a much more accurate delivery system.

It will be noted that larger effects radii and smaller CEP's increase the expected fractional damage, and that smaller effects radii and larger CEP's decrease the expected fractional damage. It cannot be categorically stated, however, that the larger the expected fractional damage, the greater the associated probability.

33. Expected Fractional Damage for Circular Targets—Non-Zero CEP

Figure 20, "Expected fractional damage, circular target, $\frac{d}{CEP}=0$," is a presentation of expected fractional damage ($\bar{f}$) as a function of R_e, R_t, and CEP for circular targets *with RGZ at target center* $\left(\text{i. e., } \frac{d}{CEP}=0\right)$. This chart is to be read directly. The probability scale used with figure 17 is not applicable to charts for expected fractional damage. Figures 21 through 24 are similar presentations of expected fractional damage but are applicable to circular targets for which the RGZ does *not* coincide with the target center. For example, figure 22 is applicable when the RGZ is offset from the target center by a distance equal to 1 CEP.

a. Example.

Given. $R_t = 1{,}000$ yards
$R_e = 1{,}000$ yards
$CEP = 500$ yards

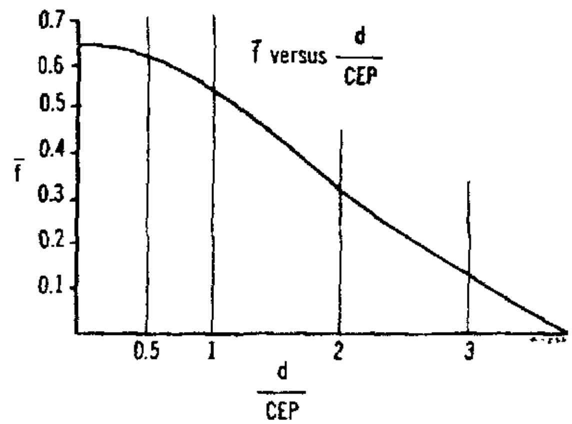
Find: Expected fractional damage for
$\frac{d}{CEP}=0$; $\frac{d}{CEP}=\frac{1}{2}$;
$\frac{d}{CEP}=1$; $\frac{d}{CEP}=2$; and
$\frac{d}{CEP}=3$.

Solution: $\frac{R_e}{CEP}=2$
$\frac{R_t}{CEP}=2$

Enter figures 20 through 24 inclusive at above values for $\frac{R_e}{CEP}$ and $\frac{R_t}{CEP}$, and read $\bar{f}$ directly, interpolating as required.

Answers:

$\frac{d}{CEP}$	$\bar{f}$
0.	0.63
0.5	0.61
1.0	0.54
2.0	0.31
3.0	0.12



It is to be expected, of course, that as the RGZ is moved a greater and greater distance away from target center, the resulting target damage will decrease. Expected fractional damage for intermediate values of $\frac{d}{CEP}$ may be obtained by interpolation.

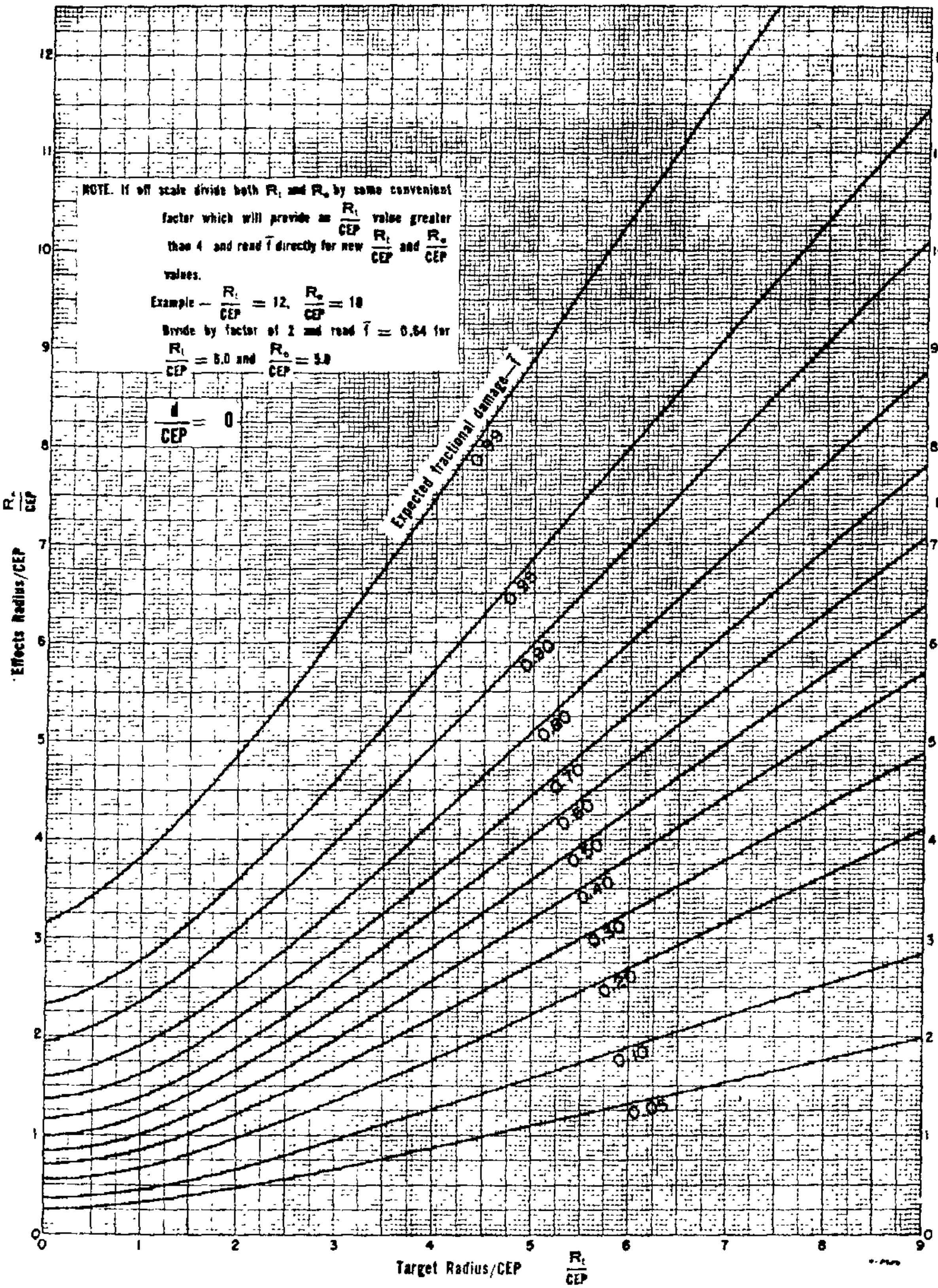


Figure 20. Expected fractional damage—$\bar{f}$ RGZ at center of a circular target, error in CEP (variability—20 percent).

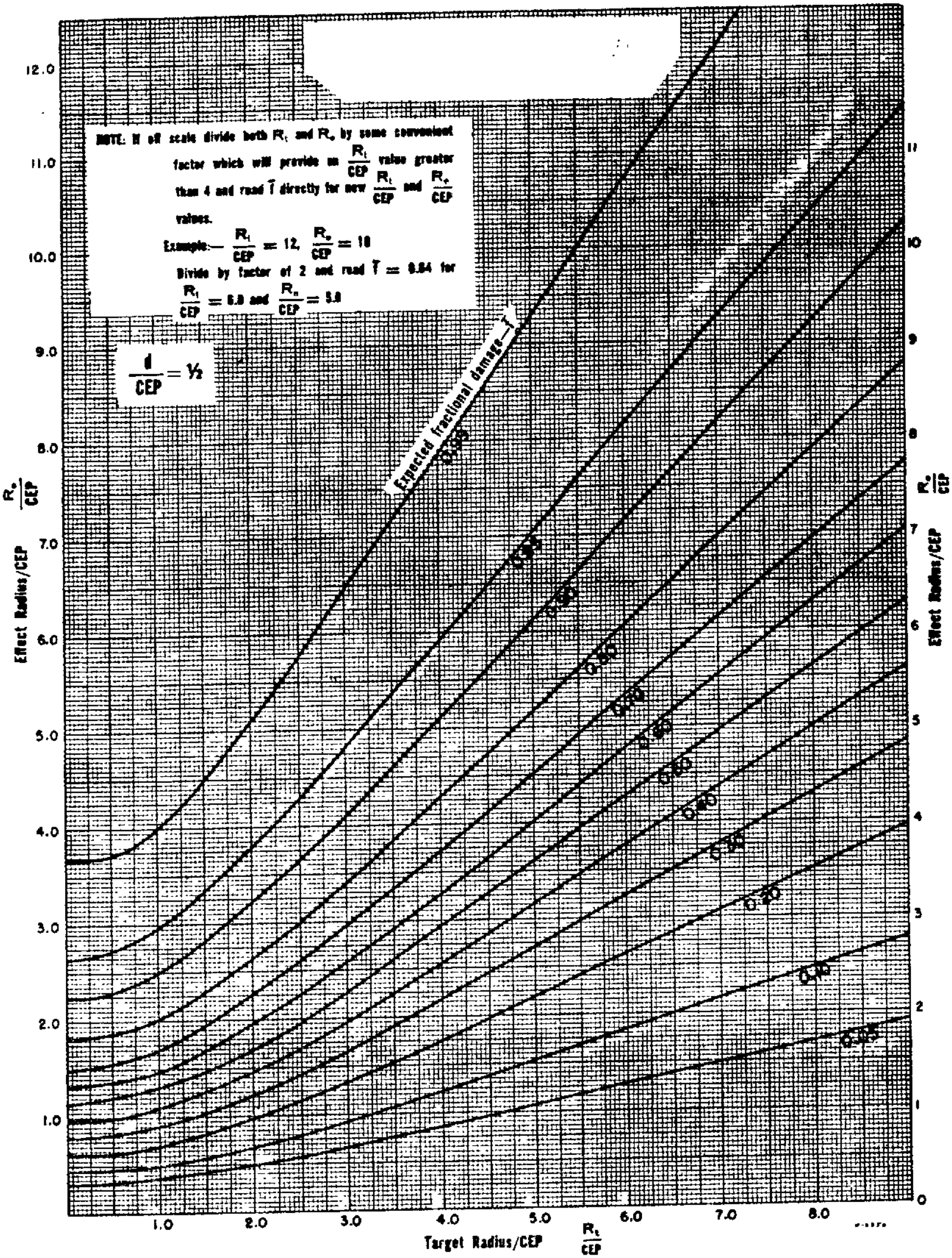


Figure 21. Expected fractional damage —$\bar{f}$. RGZ offset ½ CEP from center of circular target (variability—20 percent).

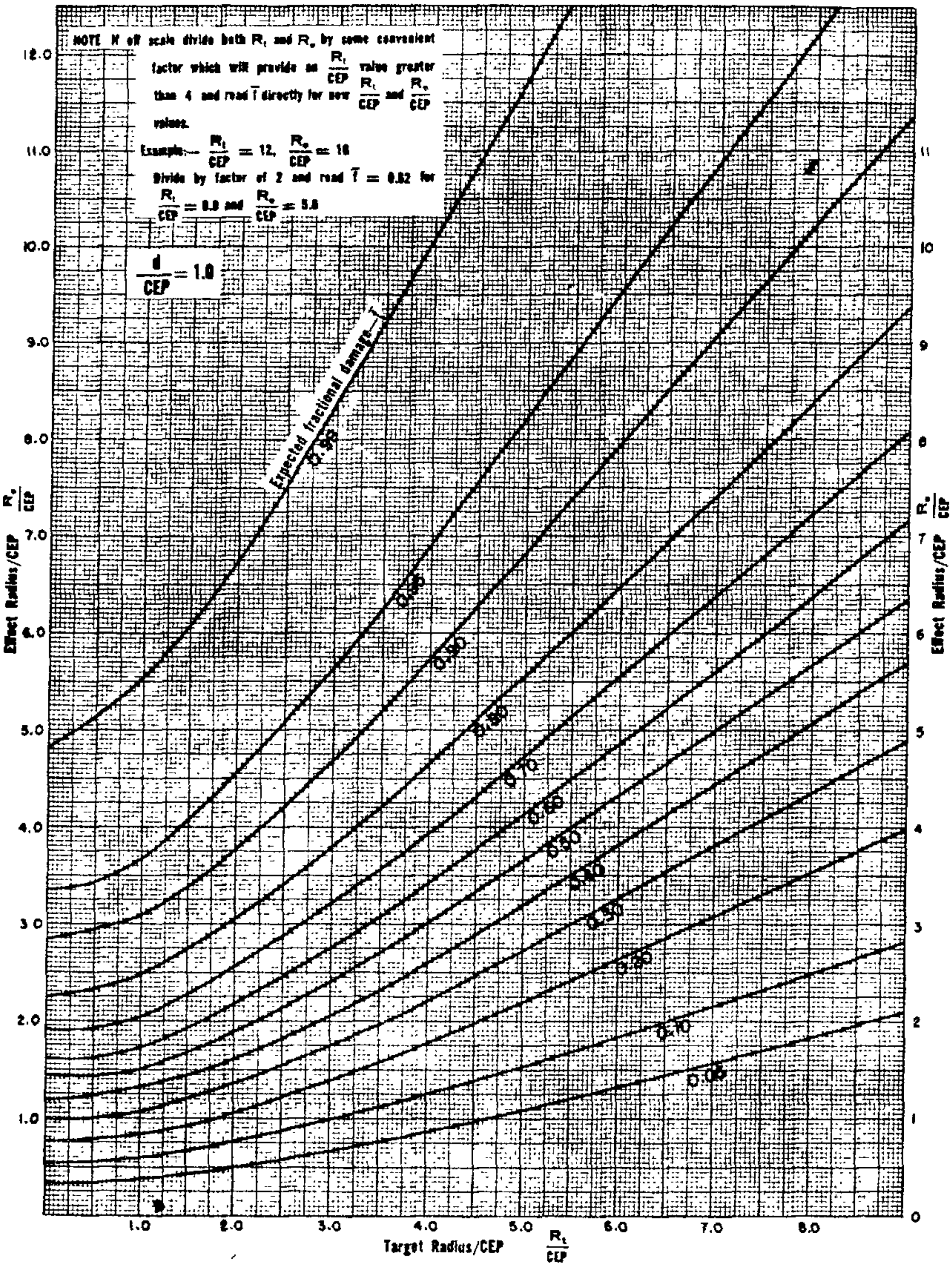


Figure 22. Expected fractional damage—$\bar{f}$. RGZ offset 1 CEP from center of circular target (variability—20 percent).

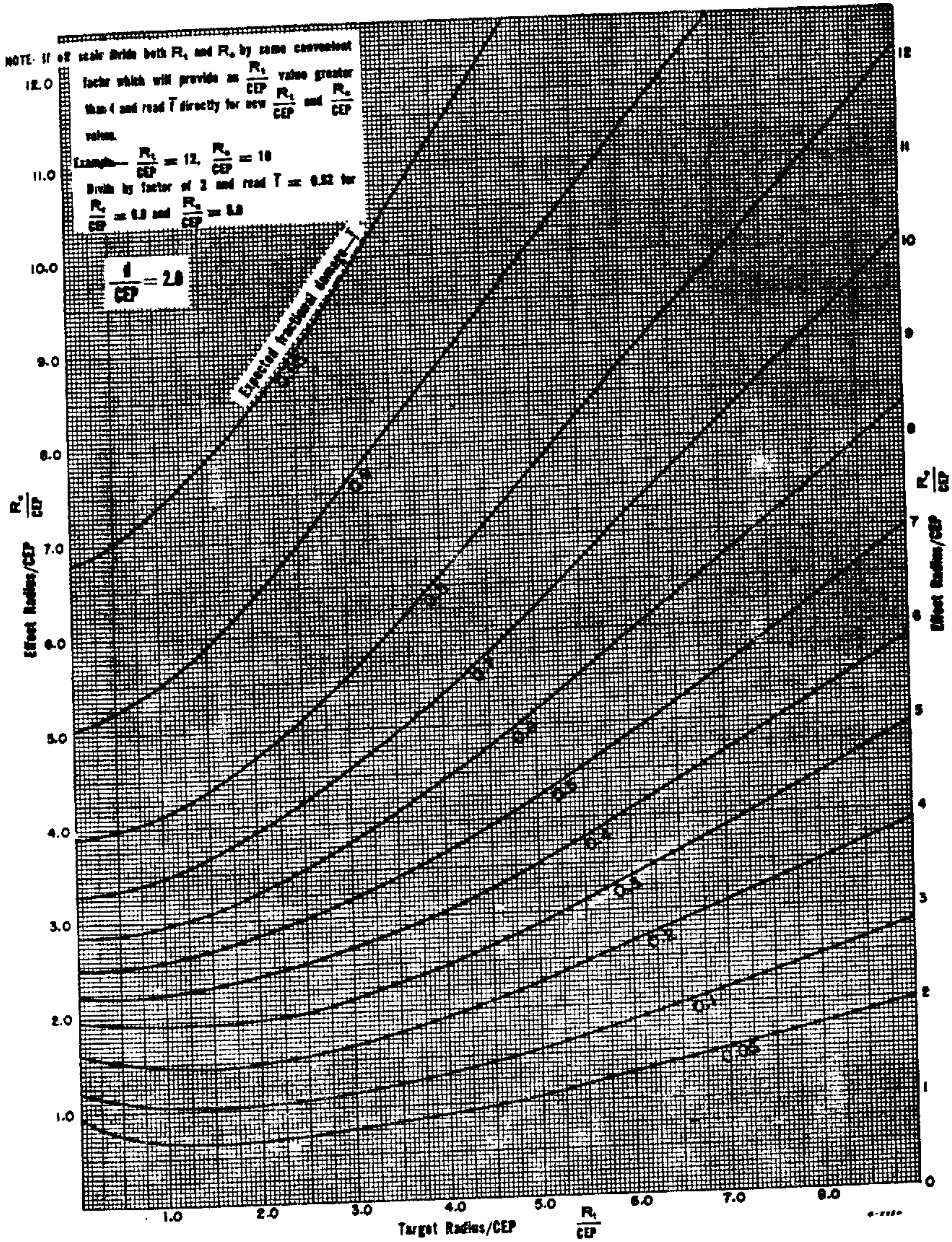


Figure 23. Expeced fractional damage—$\bar{f}$. RGZ offset 2 CEP from center of circular target (variability—20 percent).

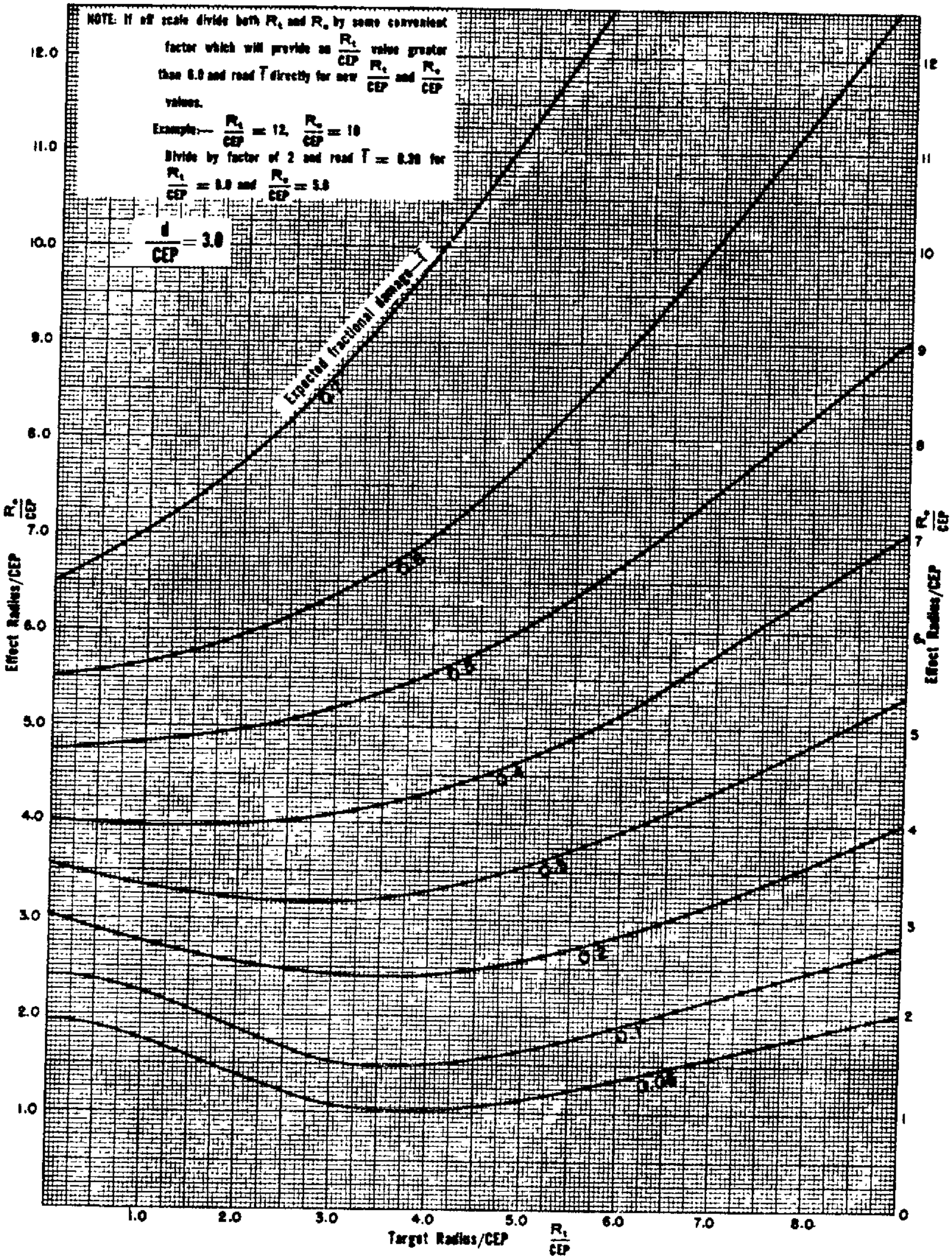


Figure 24. Expected fractional damage—$\bar{f}$ RGZ offset 3 CEP from center of circular target (variability—20 percent).

b. Example.

Given: $R_t = 1{,}000$ yards
CEP = 500 yards
RGZ 1 CEP from target center.

Find: R_e to effect an expected fractional damage of 0.7.

Solution $\frac{R_t}{CEP} = 2$

Enter figure 22 at $\frac{R_t}{CEP} = 2$ and find intersection with $\bar{f} = 0.7$; read $\frac{R_e}{CEP} = 2.55$.

Answer: Required $R_e = 2.55$ CEP
$= 2.55$ (500)
$= 1.275$ yards

Note. If the target were a city (fig. 2), the CHARLIE weapon detonated at low air burst would cause slightly more than the requisite expected damage. If this weapon and burst height were used:

$$\frac{R_e}{CEP} = \frac{1{,}330}{500} = 2.66$$

$$\frac{R_t}{CEP} = \frac{1{,}000}{500} = 2.00$$

Enter figure 22 at these values and read $\bar{f} = 0.73$.

34. Expected Fractional Damage for Circular Targets—ZERO CEP

Just as for point targets (par. 29), there are three instances when zero CEP is appropriate for area targets: when the artillery delivery system is used for the ABLE, BAKER, and CHARLIE weapons; when the actual ground zero is known from post-strike data; and when the CHARLIE weapon is prepositioned. In all three of these instances figure 17 is applicable, except that the probability scale associated therewith is *not to be used.* This is because, for zero CEP, there is no probable delivery error, hence no probability is involved. The technique of using figure 17 consists simply of replacing CEP, in the ratio $\frac{CEP}{R_t}$, with the distance (d) from target center to the actual ground zero, and then reading the f-contours at the intersection of the values for $\frac{R_e}{R_t}$ and $\frac{d}{R_t}$. Interpolation may be required. The f-contour value read will be approximately an expected fractional value.

a. Target Center at Ground Zero. In this case d is zero. Hence $\frac{d}{R_t}$ is also zero, and an approximation must be resorted to since figure 17 does not include zero value for $\frac{d}{R_t}$. In making the approximation read the f-contour value, at the appropriate $\frac{R_e}{R_t}$ ratio, along the left edge of the figure—i. e., for $\frac{d}{R_t} = 0.145$ which is as close to zero as the nomograph permits.

(1) *Example.*

Given: $\frac{R_e}{R_t} = 1.0$, and a prepositioned weapon at target center.

Find: The expected fractional damage.

Solution: Enter figure 17 at $\frac{R_e}{R_t} = 1.0$ and interpolate between f-contours along the left edge of the nomograph. Read $\bar{f} = 0.85$.

(2) *Example.*

Given: $R_t = 1{,}000$ yards, and a prepositioned weapon at target center.

Find: Required R_e for $\bar{f} = 0.60$.

Solution: Enter left edge of figure 17 at $\bar{f} = 0.6$ and read $\frac{R_e}{R_t}$ at that point. Read $\frac{R_e}{R_t} = 0.77$

Required $R_e = 0.77\ R_t$
$= 0.77$ (1,000)
$= 770$ yards.

b. Target Center not at Ground Zero.

(1) *Example.*

Given: A prepositioned weapon offset from target center by 750 yards. $R_t = 1{,}000$ yards. $R_e = 1{,}500$ yards.

Find: Expected fractional damage.

Solution: d = 750 yards.

$$\frac{d}{R_t} = \frac{750}{1{,}000} = 0.75$$

Enter figure 17 at $\frac{d}{R_t} = 0.75$ and find intersection with $\frac{R_e}{R_t} = 1.5$; read $\bar{f} = 0.84$.

(2) *Example.*

Given: $R_t = 1{,}000$ yards
d = 500 yards

Find: R_e for $\bar{f} = 0.8$

Solution: Enter figure 17 at $\frac{d}{R_t} = 0.5$, find intersection with $\bar{f} = 0.8$, read $\frac{R_e}{R_t} = 1.18$.

Required $R_e = 1.18\ R_t = 1{,}180$ yards

Note: The BAKER weapon at low air-burst height will suffice for damage to cities (fig. 2).

35. Expected Fractional Damage for Point Targets

For point targets the probability of damage is to be considered as synonomous with fractional damage. Hence, for point targets, any probability determined from figures 13 and 14 is to be considered as an expected fractional damage. This is pertinent when, and only when, an area target is considered as if it were a point target.

36. Area Targets Versus Point Targets

Figure 13 for *point* targets, when taken together with figure 14 the extension to figure 13, permits the estimation of probability of damage (i. e., expected fractional damage) to a point target irrespective of its location with respect to RGZ. Figure 17 for probability of damage to *circular* targets is suitable, except in the case of zero CEP, only if the target center coincides with RGZ. Figures 20 through 24 for expected fractional damage to circular targets are suitable when the RGZ is displaced not to exceed three CEP from target center. In other words, as a general rule in the restrictive-scope casualty-and-damage-estimation system set forth in this pamphlet, *circular targets the RGZ for which is displaced from target center a distance in excess of three CEP are to be considered as point targets* for purposes of casualty and damage estimation. This is a restriction which is imposed for reasons of simplicity only, and would not be imposed upon a special weapons adviser making a comprehensive target analysis. To partially obviate this restriction, circular targets more than three CEP removed from RGZ may be treated as a system of points by the method of the following paragraph as illustrated in figure 27.

37. Irregularly Shaped Targets
(par. 30*b*)

a. General. The P-f nomograph and the charts for expected fractional damage included in this text are suitable only for circular targets or point targets. Many area targets exist which are not circular. Common target shapes other than circular are rectangular, generally elliptical, and wholly irregular. This text will consider only four target shapes:

(1) *Circular targets* (figs. 17 and 20 through 24).

(2) *Generally circular targets.* Included in this category are all targets which are roughly circular, or can be so considered without serious error. Examples are—

(*a*) *Rectangular targets.* Targets roughly rectangular in shape with the long side less than two times the short side can be reduced to an equivalent circular area without serious error. In using the charts and nomographs, R_t should be equated to the radius of the circle of equivalent area. If the sides of the rectangle are X and Y, then,

$$R_t=\left(\frac{XY}{\pi}\right)^{1/2}=0.564\sqrt{XY}$$

See figure 25 for alignment chart for use in solving this equation.

(*b*) *Elliptical targets.* If the long axis is less than twice the short axis, the area may be equated to that of a circle with no serious error. ($R_t=\frac{1}{2}\sqrt{ab}$, where a and b are the lengths of the major and minor axes respectively.) The area may also be found by approximation, by planimetering, or by counting grid squares. See figure 26 for alignment chart for use in solving R_t of circular target of equivalent area.

(3) *Point targets.* (figs 13 and 14.)

(4) *Irregular targets.* Targets which are not amenable to reduction to a circular target of equivalent area must be considered as a system of points. In doing this the target should be considered as a series of small geometric subareas of such size that no single dimension of any one subarea will exceed the CEP of the delivery system. By assigning weighted values to key points of each subarea and finding the individual probabilities of damage to each key point, an overall average probability can be obtained with fairly reliable results (fig. 27). This overall average probability is the expected fractional damage ($\bar{f}$) of the irregular target.

1. CHART ENABLES DETERMINATION OF RADIUS (R_t) OF CIRCLE OF AREA EQUIVALENT TO AREA OF RECTANGLE OF LARGER SIDE (X) AND SMALLER SIDE (Y)
2. CHART IS NOT APPLICABLE IF X/Y EXCEEDS 2.
3. IF X/Y EXCEEDS 2, DAMAGE ESTIMATION TO RECTANGULAR TARGETS SHOULD BE BASED ON METHOD OF MULTIPLE POINT AVERAGING

EXAMPLE

1 GIVEN: RECTANGULAR TARGET WITH X = 3000, Y = 2000

2 FIND: R_t FOR CIRCLE OF EQUIVALENT AREA.

3 METHOD:

a USING SCALES (4) AND (5) DETERMINE FROM SCALE (6) THAT X/Y IS LESS THAN 2.0

b USING SCALES (1) AND (4) DETERMINE POINT OF INTERSECTION WITH SCALE (2)

c AT INTERSECTION WITH SCALE (2) GO HORIZONTALLY TO SCALE (3) AND READ R_t = 1380 YARDS.

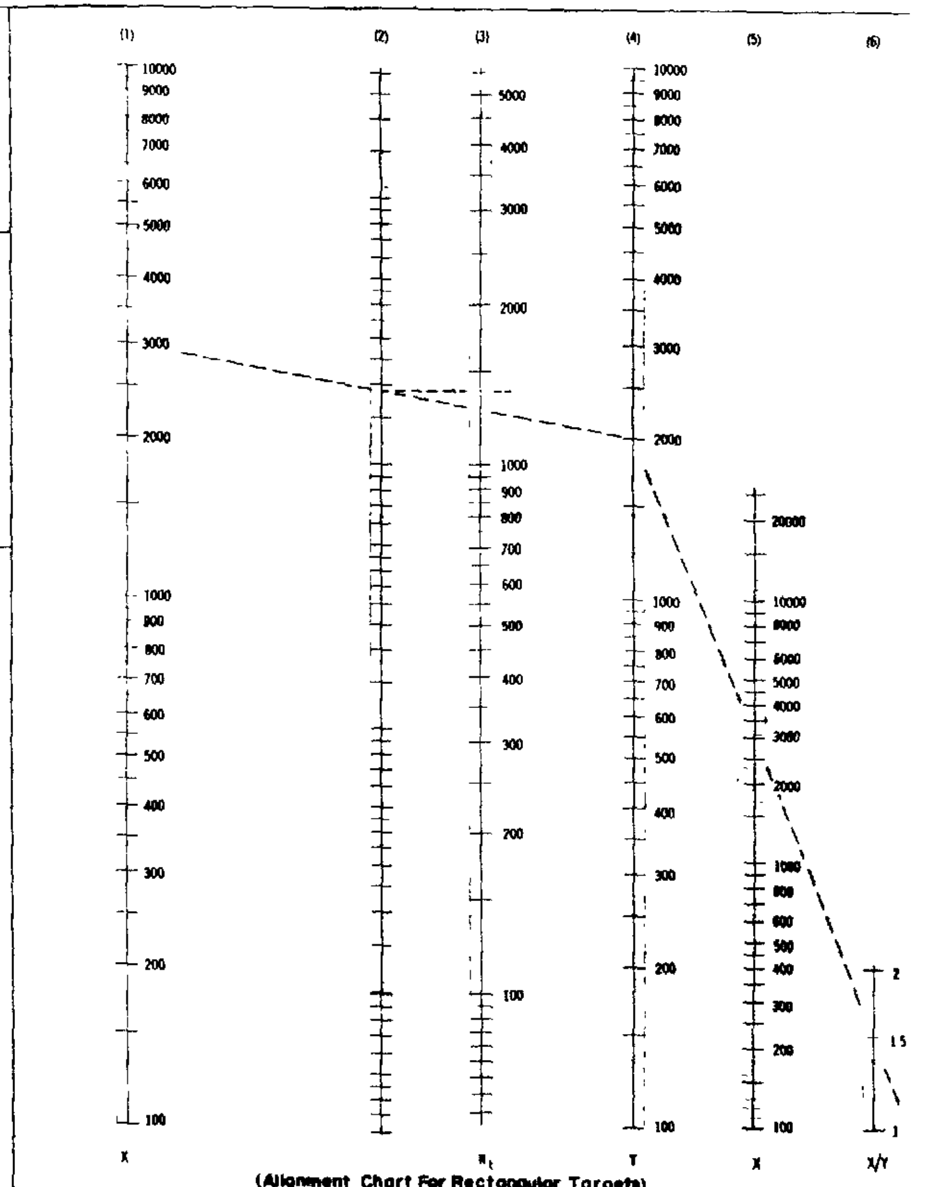


Figure 25. Alignment chart for rectangular targets.

1 CHART ENABLES DETERMINATION OF RADIUS (R_t) OF CIRCLE OF AREA EQUIVALENT TO AREA OF ELLIPSE OF MAJOR AXIS (b) AND MINOR AXIS (a).

2 CHART IS NOT APPLICABLE IF b/a EXCEEDS 2

3 IF b/a EXCEEDS 2, DAMAGE ESTIMATION TO ELLIPTICAL TARGET SHOULD BE BASED ON METHOD OF MULTIPLE-POINT AVERAGING.

EXAMPLE

1 GIVEN: ELLIPTICAL TARGET WITH
b = 1000 a = 600

2 FIND: R_t FOR CIRCLE OF EQUIVALENT CIRCULAR AREA.

3 METHOD

a USING SCALES (4) AND (5) DETERMINE FROM SCALE (6) THAT b/a IS LESS THAN 2.0

b USING SCALES (1) AND (4) DETERMINE POINT OF INTERSECTION WITH SCALE (2)

c AT INTERSECTION WITH SCALE (2) GO HORIZONTALLY TO SCALE (3) AND READ R_t = 387 YARDS.

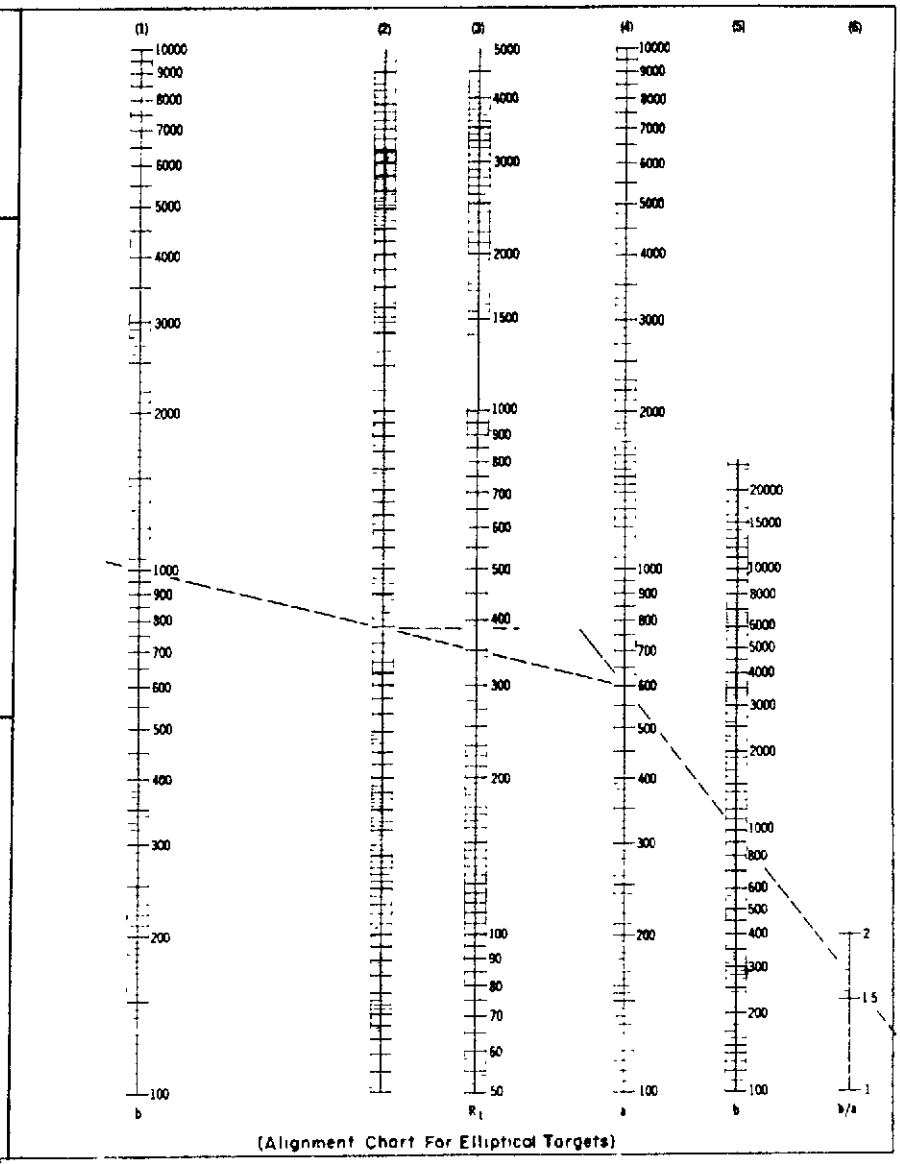
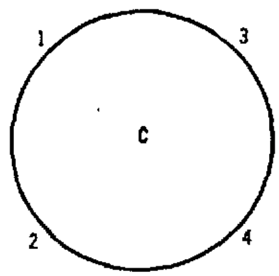


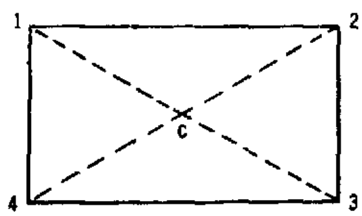
Figure 26. Alignment chart for elliptical targets.

1. CIRCLE



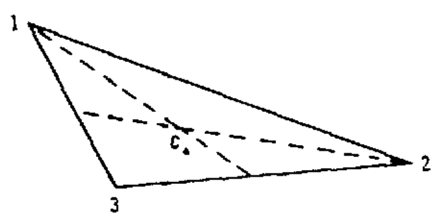
$$\bar{f} = P_{average} = \frac{P_1 + P_2 + P_3 + P_4 + 4(P_c)}{8}$$

2. RECTANGLE



$$\bar{f} = P_{average} = \frac{P_1 + P_2 + P_3 + P_4 + 6(P_c)}{10}$$

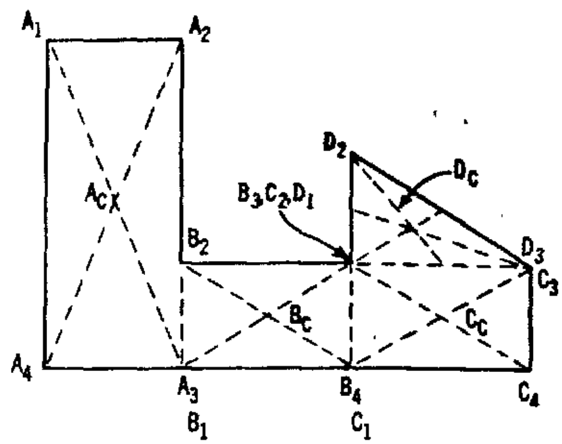
3 TRIANGLE



$$\bar{f} = P_{average} = \frac{P_1 + P_2 + P_3 + 7(P_c)}{10}$$

4. COMBINATION TARGETS

Break up into geometric subareas and solve as indicated.



Let A_C, B_C, C_C, and D_C represent centers of various geometric subareas *A, B, C, D*.

NOTE: 1. Corners common to more than one subarea are included in probability estimations for each.

2. Weights for each point depend upon basic shape of each subarea.

3. Total weights = 40 (applicable to above Fig only).

4. Answers are valid when maximum dimension of each component is less than 1 CEP.

$$\bar{f} = P_{average} = \frac{P_{A_1} + P_{A_2} + P_{A_3} - P_{A_4} + 6(P_{A_C}) + \cdots\cdots 7(P_{D_C})}{40}$$

P refers to point-target probability.

Figure 27. Expected fractional damage by multiple-point averaging.

b. Examples.

(1) *Given:* A rectangular target, with sides in ratio 1 to 1.5, the center of which is 2.5 CEP from RGZ, 2 corners (numbers 1 and 2 per fig. 27) of which are 2.0 CEP from RGZ, and 2 corners of which are 3.0 CEP from RGZ.

$R_e = 3{,}000$ yards

$CEP = 1{,}000$ yards

Find: By the method of multiple-point averaging, the expected fractional damage to the target.

Solution:

$$\left.\begin{aligned} P_1 &= 0.78 \\ P_2 &= 0.78 \\ P_3 &= 0.45 \\ P_4 &= 0.45 \\ P_{center} &= 0.64 \end{aligned}\right\} \text{from figure 13}$$

$$P_{average} = \frac{P_1 + P_2 + P_3 + P_4 + 6(P_c)}{10} = \bar{f}$$

$$P_{average} = 0.63 = \bar{f}$$

(2) *Given:* A circular target the center of which is 5 CEP removed from RGZ, points 1 and 2 of which are 6 CEP removed, and points 3 and 4 which are 4 CEP removed.

$$\frac{R_e}{CEP} = 3.0$$

Find: $\bar{f}$ for the target.

$$\left.\begin{aligned} P_1 &= 0 \\ P_2 &= 0 \\ P_3 &= 0.14 \\ P_4 &= 0.14 \\ P_c &= 0.02 \end{aligned}\right\} \text{from figure 13}$$

$$P_{average} = \frac{P_1 + P_2 + P_3 + P_4 + 4P_c}{8} = \bar{f}$$

$$P_{average} = 0.045 = \bar{f}$$

38. Concept of Military Worth and Its Relation to Complex Targets

When a target consists of several different components each of which may be considered as an individual subtarget, the overall expected fractional damage for the target is the average of the subtarget expected damage fractions. When the subtargets do not have equal value as a target, insofar as the success of the atomic strike is concerned, the concept of military worth must be considered. *For example:* if a target consists of 2 subtargets 1 of which is deemed twice as essential as the other to the success of the strike, that 1 must be given double weight in estimating the expected damage fraction. If $\bar{f}_1 = 0.8$, and $\bar{f}_2 = 0.5$ and subtarget 1 is twice as important as subtarget 2, then $\bar{f}$ for the target complex is—

$$\bar{f} = \frac{(2 \times 0.8) + (1 \times 0.5)}{3} = 0.70$$

This weighted-average method holds true regardless of the number of subtargets in the complex provided the expected damage fraction, not just any damage fraction, are the ones averaged. The determination of the relative subtarget military worths is a command decision.

39. Relationship Between Fractional Damage and Number of Casualties

a. General. It has been stated (par. 30c) that the degree of damage is called fractional damage, or damage fraction. Hence, if 1,000 troops populate a target and all are exposed to the effects of a weapon imposing a personnel casualty-producing damage fraction of 0.8, then 800 troops (1,000×0.8) can be anticipated as casualties. Likewise if of the 1,000 troops, only 500 were exposed to the effects, only 400 casualties (500×0.8) would be anticipated. This relationship holds whether the target elements are personnel, tanks, or anything else, provided the damage or casualty-producing effect is applicable to the type of target element present. (*For example:* no tanks will be damaged simply and solely by the fact that a damage fraction of 0.8 is imposed on a tank park by initial gamma radiation intended for tank-park personnel.) This relationship holds true, also, whether the damage fraction is an "expected" fraction or not. *For example:* if there is a 0.9 probability that a 0.8 damage fraction to exposed personnel will result in a certain instance, then there is a 0.9 probability that 800 of every 1,000 exposed personnel will be casualties.

b. Relationship to Technique of Damage Estimation. This relationship has pertinent significance in those instances where some target elements are shielded and others are exposed, and where it is desired to impose a certain percentage of casualties to personnel in a target area (or damage to tanks, etc., in a target area). Suppose, for example, that a given target area contains an estimated 10,000 troops, and that it is estimated that 5,000 are shielded from atomic weapon effects. Also, that it is desired that at least 30 percent of the target personnel be made casualties. The number of casualties to be obtained is, therefore, at least 3,000 which is 0.6 of the *exposed* target personnel. A damage fraction of 0.6 must, accordingly, be imposed to meet the requirements laid down.

c. Estimation of Shielding. The shielding which is present must be estimated. Sometimes this is easy and sometimes it is difficult. To cite an example of a difficult instance: suppose 1,000 troops are in a woods. Figure 4 indicates that they are susceptible to initial gamma radiation. Figure 3 indicates that they are not susceptible to thermal radiation. However, if the woods offer

very little line-of-sight shielding because of the lack of foliage on the trees, these personnel would be susceptible to thermal radiation *to the extent that they are not shielded*. This is a judgment factor. If it were judged that the woods offered 50-percent shielding, then 500 troops could be considered as being exposed to thermal radiation, as well as initial gamma radiation, and treated as if they were personnel in the open.

40. Relationship Between Probability of Damage and Distance From RGZ in any Given Instance

a. General. Oftentimes it may be desired to prepare a probability scale expressing the relationship between probability of damage to a given class of target and distance from RGZ. In any given instance R_e for each class of target (personnel in open, tanks, personnel in foxholes, etc.) will be known, as will CEP. Thus, $\frac{R_e}{CEP}$ will be known. Figure 13 then enables preparation of the desired scale. This is done by entering figure 13 at the known value for $\frac{R_e}{CEP}$ and tabulating the distances (in terms of $\frac{d}{CEP}$ which can easily be converted to yards) applicable to each probability, and preparing the scale accordingly. *For example*, if $\frac{R_e}{CEP}=3$, and CEP=1,000 yards then the following tabulation results.

P	$\frac{d}{CEP}$	d (yards)
0.99	----------	----------
0.95	1.1	1,100
0.90	1.5	1,500
0.85	1.75	1,750
0.80	1.97	1,970
0.75	2.15	2,150
0.70	2.32	2,320
0.65	2.47	2,470
0.60	2.62	2,620
0.55	2.75	2,750
0.50	2.85	2,850
0.45	3.00	3,000
0.40	3.15	3,150
0.35	3.27	3,270
0.30	3.42	3,420
0.25	3.57	3,570
0.20	3.73	3,730
0.15	3.83	3,830
0.10	4.18	4,180
0.05	4.58	4,580
0.01	5.15	5,150

b. Map Representations. This method is also applicable when it is desired to draw on a map a circle representing the distance to which the probability of point-target damage will be at least so much. Thus, such a circle for P=0.7 would, in the previous instance, be one of radius 2,320 yards. Map representations similar to this, but on an area rather than a distance basis, may be prepared using figure 17.

41. Selection of an RGZ

a. General. When troop safety is not a factor for consideration, the selection of a best RGZ is a function of the weapon-effect radius, the delivery error, and the target composition. For area targets of uniform density, the geometric center is usually the best RGZ; and for point targets, the point itself. For target complexes which consist of several components, the problem is less easily resolved. The best RGZ under these conditions is that which will ensure the maximum average probability of damage, i. e., the maximum expected fractional damage applicable to the target complex. When point-target elements are not of the same military worth, the individual probabilities *of damage to each must be weighted accordingly.* When area-target elements are not of the same military worth, the individual expected damage fractions must be weighted accordingly.

b. Point-Target Complex. In simple point-target complexes consisting of 2 elements or 3 elements, the geometric center of the complex is easily located. The best RGZ for a target complex is that which gives the highest average damage to the target complex. This may or may not *be the geometric center of the complex, depending* upon the distance from the center of the complex to the target elements. This is illustrated in figure 28 below for 3-element point-target complexes consisting of uniformly spaced target elements. It will be noted in figure 28 that, as the target complex increases in size, the best RGZ shifts from the center of the target complex (c), to the center of 1 side of the complex (b), and finally to 1 of the target elements themselves. For most target complexes of the general type illustrated in figure 28, the best RGZ is generally either the center of the complex or one of the target elements. Rarely will the center of one side (b) be the best RGZ. Preparation of a probability diagram, as illustrated in figure 28, enables ready selection of

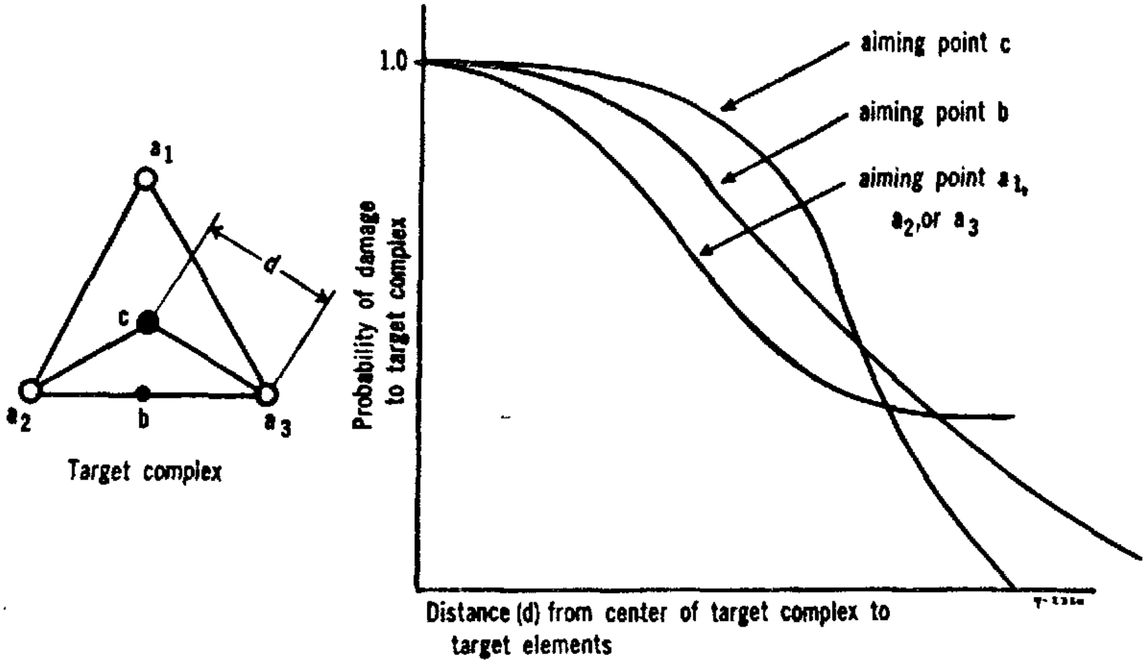


Figure 28. Optimal aiming point for uniformly spaced 3-element target complex.

	1	2	3	4	5	6	7
1	Target and delivery conditions	Point targets (fig. 13)	Point targets extension (fig. 14)	P(f) Nomograph (fig. 17)	$\bar{f}$ Charts (fig. 20, 21, 22, 23, 24)	No chart available	Remarks
2	1. CIRCULAR TARGETS						
3	*a. To get P(f) value.*						
4	(1) Center RGZ						
5	Non-zero CEP			X			Requires use of probability scale.
6	Zero CEP					X	
7	(2) Offcenter RGZ					X	
8	*b. To get expected fractional damage ($\bar{f}$).*						
9	(1) Center RGZ						
10	Non-zero CEP				X		Fig. 20 only.
11	Zero CEP			X			Do *not* use probability scale.
12	(2) Offcenter RGZ						
13	Non-zero CEP				X		Fig. 21 through 24.
14	Zero CEP			X			Do *not* use probability scale.
15	2. POINT TARGETS						
16	*a. Center RGZ*						
17	Non-zero CEP	X					
18	Zero CEP		X				
19	*b. Offcenter RGZ*						
20	Non-zero CEP	X	X				Use extension if required.
21	Zero CEP		X				
22	3. IRREGULAR TARGETS	Reduce to equivalent circular area or use method of multiple-point averaging.					

Figure 29. Index chart to damage estimation charts and nomographs.

the best RGZ for a given weapon and delivery system.

Another approach to a point-target complex is to draw about each point target respectively an R_s circle of such a size as will ensure the required probability of damage to that point, and then to choose an RGZ *within the area of overlap of* all such circles. This will usually require testing several trial RGZ, within the area of overlap, to determine the one which yields the highest average probability of damage.

c. Area-Target Complex. A complex of several subareas may be attacked with a single weapon per subarea, or by considering the area occupied by two or more subareas together as a single target *for a single weapon*. The latter makes necessary the determination of the equivalent circular area (and equivalent R_t) for the area of that portion of the complex considered as a single target. Such complexes may also be considered as a number of individual areas offset from a single RGZ. In this case figures 20 through 24 (or fig. 13) are applicable, and the best RGZ is that which gives the highest overall average of the individual expected damage fractions.

42. Index Chart to Damage Estimation Charts and Nomographs

Figure 29 is an index to the utilization of the various probability nomographs and charts of this section and has been prepared to facilitate their correct application.

Section VI. TROOP SAFETY

43. General

The employment of atomic weapons in close-support tactical roles creates a problem of troop safety. The degree of risk is indicated by the relationships between what would be a minimum safe distance under a *no-delivery-error condition* and a necessarily greater distance under the usual conditions when delivery errors are probable.

The position of any friendly troops or vital equipment with respect to a planned atomic attack must take into consideration the weapon phenomena and delivery accuracy.

Upon selection of an RGZ considered to produce the desired degree of damage to a target, the distance to the nearest friendly troops must be determined if troop safety is affected. This measured distance must not be exceeded by the weapon effects radius for the particular weapon effect established by high-echelon policy, or command decision, as the maximum to which friendly troops can be subjected, even though the actual ground zero may be different from the intended ground zero. Although this distance is fixed on the ground for a specific situation, it is affected by factors beyond human control, such as weather, terrain, and particularly by delivery inaccuracies.

44. Threshold Effects Radius

The threshold effects radius is defined as the *minimum* radius corresponding to a weapon effect intensity insufficient to cause light damage. It therefore is greater than the radius corresponding to a weapon effect intensity which will cause light damage (par 13). The *minimum safe distance* between an intended ground zero and friendly troops is the *sum of the threshold effects radius for troop safety*, R_s (which is determined by the effects criteria which the commander is willing to accept on his own troops), *plus a buffer distance* which ensures the desired factor of safety necessitated because of probable errors inherent in delivery. The value of the criteria must be determined by the tactical situation, disposition of friendly troops, and amount of forewarning and preparation. High-echelon policy, or command decision, may dictate the maximum criteria for guidance purposes with eventual responsibility being delegated to the commander exercising authority to employ atomic weapons.

For purposes of this text the threshold effects radii for troop safety, and for the safety of vital communications equipment, are fixed as tabulated in figure 30. This is a simplification measure which imposes arbitrary restrictions not ordinarily imposed on special weapons advisers. For example, if a CHARLIE weapon is detonated at high air burst in the presence of friendly troops in the open, the applicable threshold effects radius for troop safety is 4,250 yards (fig. 30). This radius is safe only if no delivery error is probable.

Weapon type and yield	Type burst	Personnel [1]				Communications equipment [6] (radio and radar)
		Troops in open or sparse woods [2]	Troops in woods [3,4]	Troops in foxholes [5]	Troops in tanks [4]	
ABLE (2-KT)	High air	1, 730	1, 340	[4] 775	865	1, 530
	Low air	1, 745	1, 360	[4] 850	890	1, 145
BAKER (15-KT)	High air	3, 850	1, 740	1, 580	1, 280	3, 010
	Low air	3, 885	1, 850	[4] 1, 495	1, 415	2, 250
CHARLIE (20-KT)	High air	4, 250	1, 780	1, 725	1, 290	3, 300
	Low air	4, 290	1, 960	[4] 1, 540	1, 430	2, 470
	Surface [7]	4, 300	2, 050	[4] 1, 575	1, 450	2, 470
	Underground	([8])	([8])	([8])	([8])	[6] 1, 650
DOG (75-KT)	High air	6, 925	2, 050	2, 720	1, 665	5, 140
	Low air	6, 990	2, 390	[4] 2, 020	1, 730	3, 850
EASY (100-KT)	High air	7, 720	2, 080	3, 000	1, 480	5, 650
	Low air	7, 790	2, 490	[4] 1, 980	1, 830	4, 150
FOX (200-KT)	High air	9, 900	2, 150	3, 770	1, 500	7, 100
	Low air	9, 980	2, 610	[4] 2, 290	2, 020	5, 325
GEORGE (500-KT)	High air	13, 650	2, 170	5, 100	1, 240	9, 650
	Low air	13, 770	3, 000	[4] 2, 370	2, 220	7, 230

[1] Based on no decrease in combat effectiveness

[2] Woods providing less than 10-percent thermal shielding.

[3] Troops shielded from thermal effects.

[4] Initial nuclear radiation governs—thermal radiation governs in all other instances involving personnel

[5] Troops in medium to deep foxholes.

[6] Based on no blast damage to equipment in the open. For dug-in equipment use a threshold effects radius *one-half that given in this column.*

[7] Troop-safety estimations must also consider residual gamma radiation in the instance of a surface burst.

[8] In the instance of an underground burst troop-safety estimations must consider (1) residual gamma radiation and (2) crater size.

Figure 30. Threshold effects radii (R_e) for troop safety [1] *and communications equipment.*[6]

(distances in yards from ground zero).

45. Buffer Distance

In order to ensure safety of friendly troops where a delivery error is probable, a distance must be allowed beyond the extent of the threshold effects radius and toward the friendly troop position. This is called *buffer distance.* If the distance from RGZ to a frontline position is 5,000 yards, and the threshold effects radius for troop safety is 4,250 yards, the buffer distance is 5,000 minus 4,250, or 750 yards. In determining the degree of calculated risk to friendly troops in close support roles, it is convenient to express this buffer distance in terms of multiples of the probable delivery error. Figure 31, "Probability of exposing friendly troops to effects of atomic weapons," expresses the relationship between degree of risk to friendly troops (or vital equipment) as a function of the ratio of buffer distance to CEP. *For example* (fig. 31), for a straight-line troop position (par. 4), and for $\frac{d_b}{CEP}=2.6$, the risk that friendly troops *will not be safe* is 1 in 1,000. Conversely, the probability that they *will be safe* is 99.9 percent.

46. Troop Positions With Respect to Atomic Detonations

It is reasonable to expect that the degree of risk to friendly troops inherent in a given instance will depend on the disposition of the friendly troops. Figure 32, "Typical troop positions," depicts five common dispositions. For the first four of these dispositions there is a separate relationship expressed in figure 31 between degree of risk and ratio of buffer distance to CEP. Figure 31 must be used in a manner to accord with the type of friendly troop disposition as depicted in figure 32. For troop dispositions intermediate to the typical positions depicted in figure 32, interpolation between the corresponding curves of figure 31 is indicated. For the fifth troop position (point target), figure 13 is applicable.

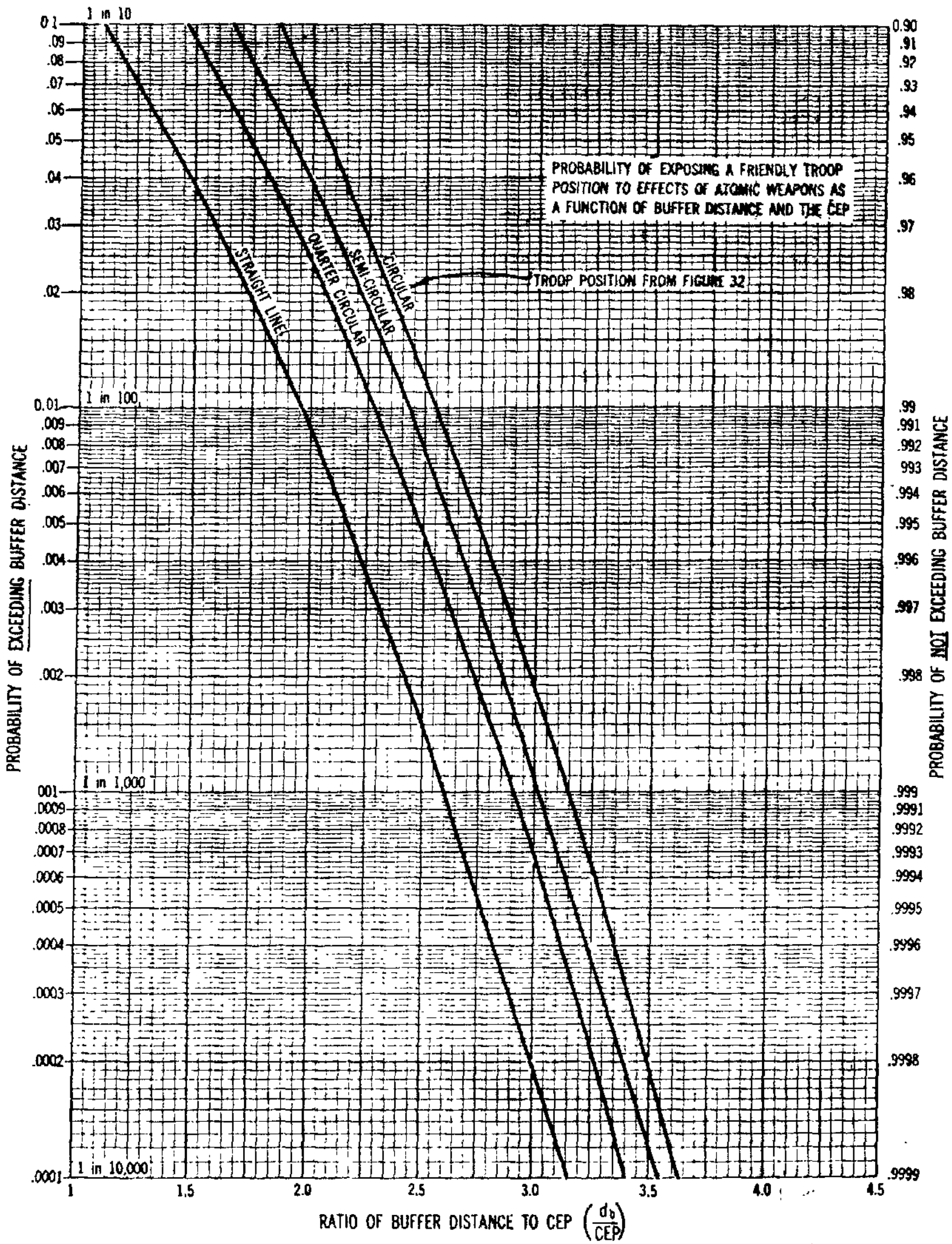


Figure 31. Probability of exposing friendly troops to effects of atomic weapons.

47. Examples

a. Given: A semicircular friendly troop position; a CHARLIE weapon detonated at high burst height; and a requirement that the risk to friendly troops in foxholes be no greater than 1 in 1,000. CEP=1,000 yards.

Required: Find the required buffer distance and the minimum safe distance between friendly troops and RGZ.

Solution: From figure 30 threshold effects $R_e = 1{,}725$ yards. Enter figure 31 at 0.001 on left scale, intersect the semicircular troop position curve, and read required $\frac{d_b}{CEP} =$ 3.02.

Required buffer distance=3.02 (1,000)= 3,020 yards.

Minimum safe distance=3,020+1,725= 4,745 yards.

b. Given: Same situation.

Required: Would troop radios be safe if left in the open at 4,745 yards?

Solution: Threshold effects radius for radios in the open=3,300 yards.

Minimum safe distance=3,300+3,020 (from preceding example)=6,320 yards.

Answer: They would *not* be safe, and would have to be given additional protection.

c. Given: Same situation.

Required: What would be the risk to troop radios in foxholes at 4,745 yards?

Solution: Threshold effects radius for radios in foxholes=1,650 yards. Available buffer distance=4,745−1,650=3,095 yards, or 3.095 CEP. Enter figure 31 at 3.095 CEP, intersect the semicircular troop-position curve, and read probability of exceeding buffer distance=0.00072.

Answer: The risk that the troop radios would be damaged is 0.72 chance in 1,000, or 0.072 percent. (This may be checked by reading from fig. 31 the probability of *not* exceeding the buffer distance= 0.99928, i. e., a 99.93 percent chance that they will be safe. Note that 0.00072 plus 0.99928=1.00000.)

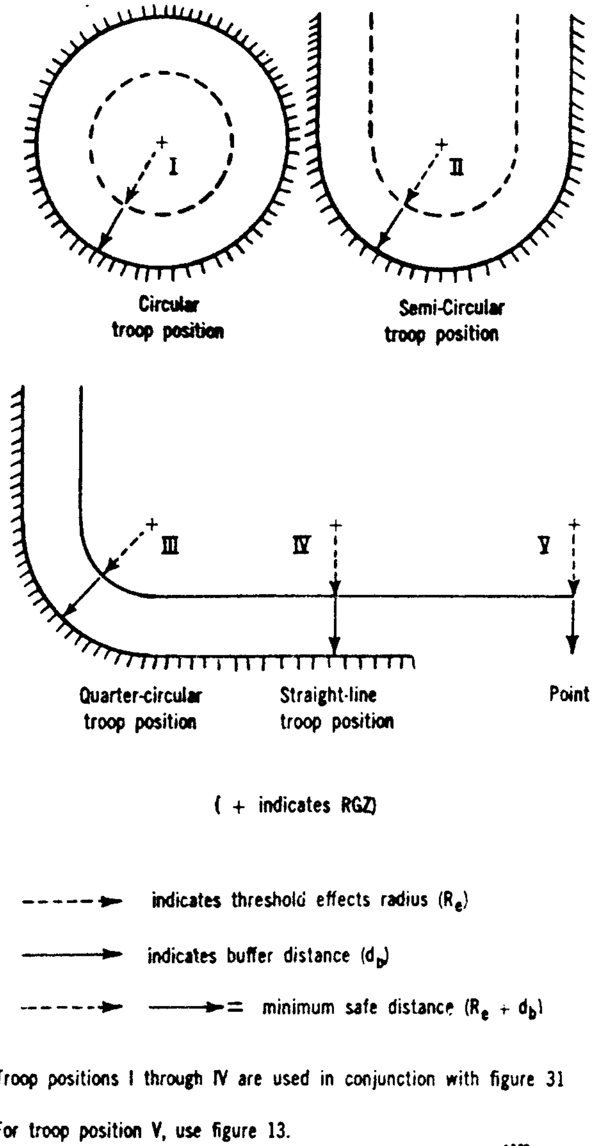


Figure 32. Typical troop positions.

Section VII. SELECTION OF WEAPONS AND DELIVERY MEANS

48. General

The selection of the weapon and delivery means is crucial to the success of a planned atomic strike. There are many factors to be considered: some technical, some tactical. This text is much concerned with the technical considerations and is concerned with the tactical considerations only as they impinge on the technical.

49. Pertinent Factors

Some of the more pertinent factors which require attention, are—

a. Weapon Availability. This must include not only actual availability, but also timely availability of weapons having the characteristics required. *For example:* only the CHARLIE weapon is capable of a surface burst.

b. Delivery System Availability. This must include actual availability, timely availability, and an ability to deliver as required under the conditions (e. g., weather) present. Considerations of adequate range, proper siting, and a capability to deliver the specific weapon chosen, are important.

c. Delivery System Accuracy. Some systems are inherently more accurate than others. On occasion this factor may govern, for example, if troop-safety assurances cannot be met otherwise.

d. Economy. The smallest weapon which will do the job should be used for economy reasons. At high air burst both the BAKER and CHARLIE weapons extend thermal effects against troops in the open (fig. 3) to practically equal distances. As between two weapons, all other factors being equal, the weapon of lower kiloton yield is preferred.

50. Minimum Essential Effects Radius

In order to select a weapon, it is necessary that the minimum essential effects radius be determined. This is the smallest effects radius which will perform the intended task. It is determined by target size and location, the delivery system CEP, and the required fractional damage and assurance of its attainment (or the required expected fractional damage). For example, if a point target 500 yards from RGZ is to be attacked with a weapon delivered by a delivery system having a 500-yard CEP, and if the probability of damaging the target must be at least [illegible], then (from fig. 13) the minimum essential $R_e = 2.05$ (500), or 1,025 yards. Any weapon chosen for this task must effect an R_e of 1,025 yards for the type of effect which is required. To extend the example further: if the target consists of communications equipment (fig. 2), the DOG weapon at low air-burst height is the minimum size weapon capable of performing the assigned task; if the target is troops in foxholes (visibility 2 miles), the CHARLIE weapon is the minimum size weapon. (Note that the CHARLIE weapon at high burst effects a *thermal* R_e of 1,040 yards, and that the CHARLIE weapon at low burst effects a *gamma* R_e of 1,025 yards. The CHARLIE weapon at either burst height would be satisfactory in performing the assigned task. The choice of burst height would depend on the bonus damage which could be obtained to secondary target elements.) If the target is troops in heavy bunkers the FOX weapon at low air-burst height is required (fig. 4).

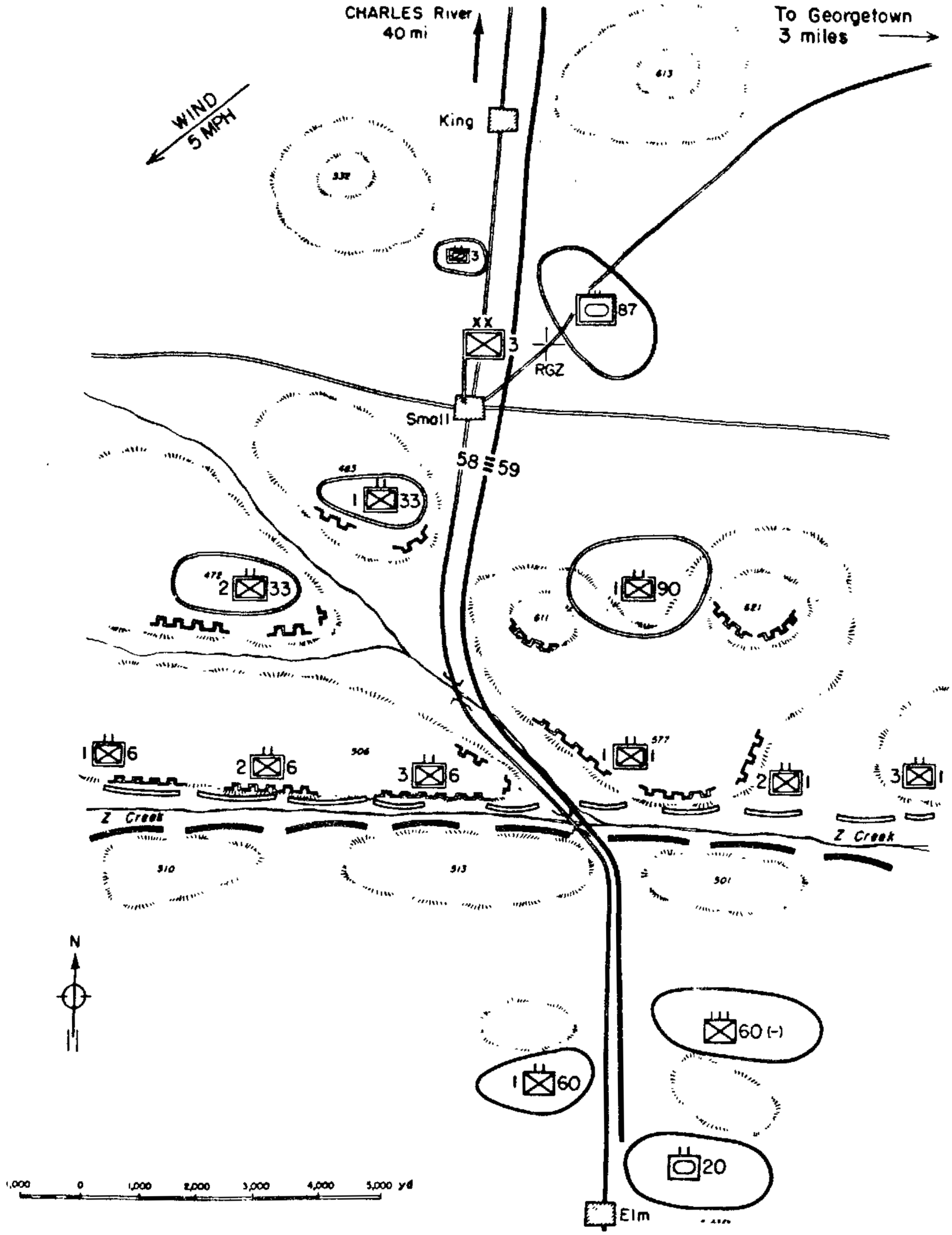


Figure 33. Sketch map for illustrative problems.

APPENDIX I

ILLUSTRATIVE PROBLEM

Part One. ILLUSTRATIVE PROBLEM A

1. General Situation

a. Map: sketch map (fig. 33).

b. Own Forces. 20th Inf. Div., part of I Corps, U. S. Thirtieth Army, is advancing north with the mission of seizing a bridgehead over the CHARLES River.

c. Enemy Forces. Enemy resistance is increasing as the CHARLES River is approached.

2. Special Situation

a. By 011900 June, 20th Inf. Div. had advanced to the line of Z Creek. (Sketch map.)

b. It is 012100 June. You are an Assistant G3, 20th Inf. Div. The G3 has asked you to study the possibility of using one atomic weapon against the reserves of the Aggressor 3d Rifle Div to assist the attack, and made the following information available to you:

(1) Enemy dispositions. See sketch map.

(2) Priority of damage to enemy forces. The commander desires—

(*a*) A minimum of 75-percent personnel casualties to the 87th Tk Regt.

(*b*) No residual nuclear radiation contamination from the strike.

(*c*) A 99-percent assurance of *not* subjecting our troops to more than the applicable threshold effects.

(*d*) No damage to the 2-lane 300-foot highway bridge 4,500 yards south of the enemy 3d Rifle Div command post.

(*e*) First priority will be given to personnel casualties in the 87th Tk Regt. Second priority will be given to the 3d Rifle Div command post.

(*f*) That a delivery system under army control (i. e., free rocket or guided missile) be given first priority consideration.

(3) Availability of atomic weapons (fig. 1).

(4) Available delivery means and CEP applicable (fig. 1). The artillery delivery system is *not* available.

(5) Weather conditions.

(*a*) Wind from the northeast approximately 5 miles per hour.

(*b*) Clear, with visibility 20 miles.

(6) It is expected that our atomic attack will have surprise and that all enemy reserve units will be virtually in the open. Tank crews will not be in their tanks. Forward infantry elements will be dug-in.

(7) Our troops are occupying hastily dug positions and cannot be considered as having foxhole protection.

(8) Estimated strength of enemy reserves.

Unit	Personnel	Armored vehicles or tanks
Division headquarters	1,000	0
Rifle battalions	1,000	6
87th Tk Regt	2,000	75
3d Recon Bn	364	10

(9) Enemy air has not been active against our aircraft.

3. Requirement

a. Prepare recommendations for—

(1) Weapon to employ.

(2) RGZ.

(3) Height of burst (high, low, surface, or underground).

(4) Delivery means.

b. Estimate the following for the weapon and delivery means recommended:

(1) The number of personnel casualties in the 87th Tk Regt.

(2) The number of tanks of the 87th Tk Regt which may be expected to be severely damaged.

(3) The number of personnel casualties in the 3d Recon Bn.

(4) The number of armored vehicles of the 3d Recon Bn which may be expected to be severely damaged.

(5) The amount of damage to and the number of personnel casualties in the 3d Rifle Div command post.

(6) The probability of destruction of the bridge 4,500 yards south of the 3d Rifle Div command post.

(7) The assurance that no friendly personnel casualties will ensue.

Solution of Illustrative Problem A

1. Target Elements

a. Primary. 87th Tk Regt with priority to personnel.

b. Secondary.

(1) 3d Rifle Div command post.

(2) Tanks and personnel of 3d Recon Bn.

(3) Tanks of 87th Tk Regt.

2. Controlling Restrictions

a. Troop Safety. Ninety-nine percent assurance of no damaging effect to our own troops.

b. Bridge South of 3d Rifle Div Command Post. No damage.

c. Residual Nuclear Radiation. None.

3. Target Size

The area of the 87th Tk Regt is generally elliptical in shape, 2,500 yards by 1,300 yards, measured. From figure 26, the radius of the circle of equivalent area is determined as 900 yards. ($R_t = 900$.)

4. Minimum Essential Effects Radius for Primary Target Element

The available delivery systems have two different CEP (fig. 1).

a. CEP = 1,000 yards:

$$\frac{R_t}{CEP} = \frac{900}{1{,}000} = 0.90$$

Entering figure 20 at this value and intersecting $\hat{f} = 0.75$ read $\frac{R_e}{CEP} = 1.72$. Accordingly, the minimum essential $R_e = 1.72\ (1{,}000) = 1{,}720$ yards, provided RGZ is at center of primary target area.

b. CEP = 500 yards.

$$\frac{R_t}{CEP} = \frac{900}{500} = 1.8$$

From figure 20, $\frac{R_e}{CEP} = 2.22$ and minimum essential $R_t = 1{,}110$ yards, provided RGZ is at center of primary target area.

5. Weapon Effect to Use

Since the primary target is personnel in the open the applicable weapon effect is thermal radiation. Thus, figure 3 is pertinent. For the secondary targets and the controlling restrictions, the following figures are pertinent.

a. Tanks. Figure 2.

b. 3d Rifle Div Command Post. Figure 2.

c. Troop Safety. Figures 30, 31, and 32.

d. Highway Bridge. Figure 2.

e. Residual Radiation. Since this must be zero, surface bursts or underground bursts are precluded.

6. Tentative Weapon Selection

To achieve an R_e of 1,720 yards (CEP = 1,000 yards) against personnel in the open (visibility 20 miles), figure 3 indicates that the BAKER (15-KT) weapon is required either at high or low air burst. To achieve an R_e of 1,110 yards (CEP = 500 yards), the BAKER weapon is also required either at high or low burst. If the BAKER weapon is used, the desired results to the primary target will be achieved since R_e will be either *1,900 yards* or *1,980 yards* depending on height of burst, provided the RGZ is not too far removed from the center of the primary target area (pars. 7 and 8).

In addition, the commander's desire to give first priority consideration to army guided-missile or army free-rocket delivery can be adhered to by using the BAKER weapon. Hence, no further consideration need be given to CEP = 1,000 yards, and the BAKER weapon is tentatively selected.

7. Tentative Height of Burst

Either high or low burst will achieve the desired results to the primary target. The secondary targets are blast susceptible, except for the personnel of the 3d Recon Bn in which case thermal radiation is indicated. It is indicated in figure 2 that the blast damage of high air-burst weapons against military equipment is negligible. For the personnel of the 3d Recon Bn a low-burst BAKER detonation will cause a larger thermal radiation R_e (fig. 3) than will a high burst. Hence a low-burst BAKER weapon is tentatively selected.

8. Tentative RGZ

Although it would appear that the center of the primary target area should be selected as the tentative RGZ, the BAKER weapon at low air burst will effect $R_e = 1{,}980$ yards whereas only 1,110 yards is required. It is therefore indicated that the RGZ be displaced away from the center of the primary target area toward the second priority target (3d Rifle Div command post) in order to achieve maximum damage to the command post and still accomplish the required personnel damage to the first priority target.

a. First Trial RGZ; 1 CEP From Primary Target Center Toward 3d Rifle Div Command Post.

Expected personnel casualties to first priority target.

$\frac{d}{CEP}=1.0$; **figure 22 is applicable.**

$\frac{R_t}{CEP}=\frac{900}{500}=1.8$

$\frac{R_e}{CEP}=\frac{1,980}{500}=3.96$

From figure 22, $\bar{f}=0.92$.

This fractional damage exceeds the 75 percent the commander desires. Hence, the trial RGZ may be even further displaced toward the second priority target.

b. Second Trial RGZ; 2 CEP From Primary Target Center Toward 3d Rifle Div Command Post.

Expected personnel casualties to first priority target.

$\frac{d}{CEP}=2$; **figure 23 is applicable.**

$\frac{R_t}{CEP}=1.8$

$\frac{R_e}{CEP}=3.96$

From figure 23 $\bar{f}=0.71$

This fractional damage is less than the 75 percent desired. Hence, the RGZ should be located between 1 and 2 CEP away from the center of the primary target center.

9. RGZ

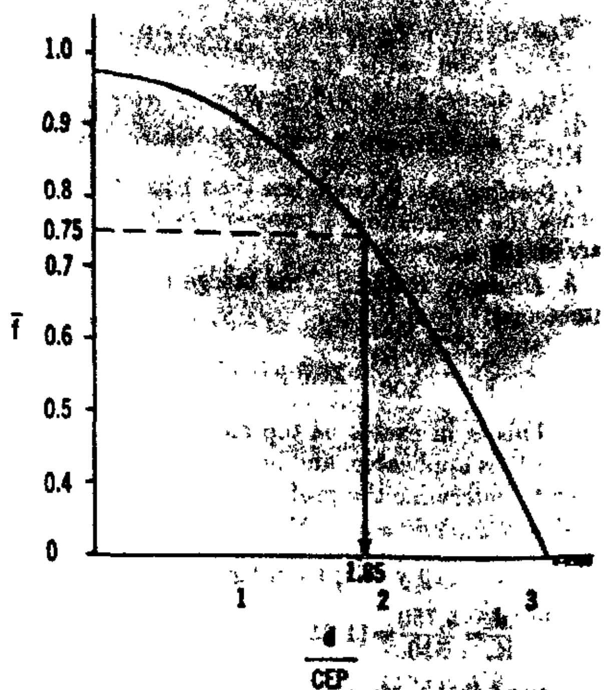
To determine the RGZ which will attain the stipulated primary target damage and the maximum second priority target damage requires interpolation between the first and second trial RGZ's. Graphical interpolation indicates that a displacement of 1.85 CEP from the primary target center is the maximum that will permit attaining the stipulated primary target damage.

a. Expected Personnel Casualties to First Priority Target. Seventy-five percent of 2,000 or 1,500 casualties, as desired by the commander.

b. Expected Damage to Secondary Priority Target—i. e., to 3d Rifle Div Command Post. The distance from the command post to the RGZ is 2,600 yards (measured) minus 1.85(500)=1,675 yards.

$$\frac{d}{CEP}=\frac{1,675}{500}=3.35$$

Hence the command post must be considered as a point target, and figure 13 is applicable.



$R_e=1,210$ **yards, from figure 2, for built-up areas.**

$\frac{R_e}{CEP}=\frac{1,210}{500}=2.42$

From figure 13, the probability of damage is 0.14. Since the probability of damage to a point target is synonymous with fractional damage (par. 35), the fractional damage to be expected in the 3d Rifle Div Command post is 14 percent. In addition, since an R_e for built-up areas is also applicable to personnel in those areas (par. 15*a*), it can be expected that casualties to personnel of the 3d Rifle Div command post will be 0.14(1,000)=140.

10. Influence of Controlling Restrictions

a. Troop Safety. The sketch map (fig. 33) indicates that the applicable troop position is "straight line." Figure 31, for a 99-percent assurance, and for a straight-line position, indicates a buffer distance requirement of 1.95 CEP; $\left(\frac{d_b}{CEP}=1.95\right)$. Since the friendly troops are in the open (see par. 2*b*(7) of situation), figure 30 indicates that the applicable threshold effects radius is 3,885 yards. Accordingly, the distance from the RGZ to the friendly troops must be not less than 3,885 yards plus 1.95 CEP; i. e., 3,885 plus 975=4,860 yards.

The distance from the line of contact to the RGZ is 7,800 yards (measured). The available buffer distance is 7,800−3,885=3,915 yards; $\frac{d_b}{CEP}=7.83$. Figure 31 then indicates that the troop-safety risk is much less than 1 in 10,000, and hence the commander's troop-safety requirements are amply met.

b. Highway Bridge. This bridge is 5,750 yards (measured) from RGZ.

$$\frac{d}{CEP}=\frac{5,750}{500}=11.5$$

This is in excess of the maximum for which figure 13 is applicable, and hence figure 14 must be used to determine the probability of damaging the bridge:

$R_e=510$ yards; from figure 2.

$$\frac{d}{R_e}=\frac{5,750}{510}=11.25$$

Figure 14 indicates a probability much below 0.01, i. e., substantially zero. Hence, no damage to the bridge can be expected.

c. Residual Radiation. No residual radiation can be expected from a low air burst.

d. Summary. All controlling restrictions are thus met by the BAKER weapon detonated at the selected RGZ at a low air-burst height of burst.

11. Recommendations

a. Weapon to Employ. BAKER, 15-KT.

b. RGZ. A distance of 925 yards from the center of the area of the 87th Tk Regt toward the 3d Rifle Div command post (see par. 9*b* above, and sketch map).

c. Height of Burst. Low air burst.

d. Delivery Means. Either guided missile or free rocket; CEP = 500 yards. The choice is one dependent upon the tactical situation at the time of the attack.

12. Estimated Results of Attack

a. Expected number of personnel casualties to 87th Tk Regt: 1,500 (see par. 9*a* above).

b. Expected number of tanks damaged in area of 87th Tk Regt.

$$\frac{d}{CEP}=\frac{1.85\times 500}{500}=1.85;$$ an interpolation between figures 22 and 23 is required.

$$\frac{R_e}{CEP}=\frac{170}{500}=0.34$$

$$\frac{P_t}{CEP}=\frac{900}{500}=1.80$$

Figure 22 indicates $\bar{f}=0.04$

Figure 23 indicates $\bar{f}=0.03$ (estimated)

Hence, $\bar{f}=0.03150$ (estimated); and the number of damaged tanks to be expected = 0.03150(75) = 2 or 3 tanks

c. Expected number of personnel casualties in the 3d Recon Bn:

$$\frac{d}{CEP}=\frac{2,500\text{ (measured)}}{500}=5.0$$

Thus, figure 13 is applicable.

$R_e=1,980$ yards; from figure 3.

$$\frac{R_e}{CEP}=\frac{1,980}{500}=3.96$$

Figure 13 indicates $P=0.15$

Accordingly, the number of casualties to be expected = 0.15(364) = 54.5, say 54.

d. Expected number of armored vehicles damaged in area of 3d Recon Bn:

$$\frac{d}{CEP}=5.0$$

$R_e=170$ yards; from figure 3.

$$\frac{R_e}{CEP}=\frac{170}{500}=0.34$$

Figure 13 indicates $P=0$; accordingly, no damage can be expected.

e. Expected fractional damage to the 3d Rifle Div command post: 14 percent (par. 9*b* above).

f. Expected number of personnel casualties in the 3d Rifle Div command post: 140 (par. 9*b* above).

g. Probability of destruction of highway bridge: zero (par. 10*b* above).

h. Troop safety: risk is less than 1 in 10,000 (par. 11*a* above).

i. Residual radiation: none (par. 10*c* above).

Part Two. ILLUSTRATIVE PROBLEM B

1. General Situation

See illustrative problem A.

2. Special Situation (Continued)

a. The atomic strike planned in illustrative problem A was delivered according to the recommendations made.

b. Followup analysis indicated, however, that an inadvertent surface burst of 20-KT resulted. RGZ was as planned.

c. A reconnaissance of the contaminated area indicated that the dose rate on the road at a point 500 yards downwind from GZ was 460 roentgens per hour ½ hour after detonation.

d. It is planned to send a work party to a point on the road 500 yards downwind from GZ. It is

estimated the party will enter the contaminated area 3 hours after detonation.

c. The commander has stipulated that no person in his command shall receive more than 50 roentgens from residual radiation in the contaminated area from this strike.

3. Requirement

a. Estimate the dose rate in roentgens per hour at the intended work point on the road 1 hour after detonation.

b. Estimate the allowable stay-time for the work crew.

Solution to Illustrative Problem B

1. Dose Rate at 1 Hour After Detonation

Figure 8 indicates a dose rate of 200 roentgens per hour at 1 hour after detonation, at the intended work point on the road.

2. Allowable Stay-Time

a. Permissible total dose = 50 roentgens.

b. Enter figure 10 at $\frac{D}{R_1} = \frac{50}{200} = 0.25$, intersect time after explosion = 3 hours; and interpolate allowable stay-time = 1.25 hours.

3. Alternate Solution to Allowable Stay-Time

a. From figure 8, the dose rate at 3 hours after detonation = 55 roentgens.

b. Enter figure 11 at $\frac{D}{R} = \frac{50}{55} = 0.908$; intersect time after explosion = 3 hours; and interpolate allowable stay-time = 1.25 hours.

[AG 461 (27 Dec 54)]

BY ORDER OF THE SECRETARY OF THE ARMY:

M. B. RIDGWAY,
General, United States Army,
Chief of Staff.

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JOHN A. KLEIN,
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Unless otherwise noted, distribution applies to ConUS and overseas command.

For explanation of abbreviations used, see SR 320–50–1.

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Ref

ATOMIC WEAPONS EMPLOYMENT

CHANGES No. 1

HEADQUARTERS,
DEPARTMENT OF THE ARMY
WASHINGTON 25, D. C., *31 May 1957*

Pamphlet 39-1, 12 June 1956, is changed as follows:

Substitute the term *Cannon* or *cannon delivery* for the term "gun" or "gun delivery" throughout the pamphlet.

Add the words (*not to scale*) to the captions of figure 6 (page 22), figure 8 (page 50), and to the captions of the sample atomic damage templates included in appendix I.

Change table VII, *Damage Radii*, page 57, as follows:

The damage radius for a BRAVO 10-KT weapon, high air burst for starting forest fires in fire season is 1,100 yards. The damage radius for a JULIETT, 5-MT weapon, for both low air and surface bursts for damage to communications equipment is 8,200 yards.

11. (Superseded) Employment Times

For planning purposes, the assumed times from receipt of the fire mission by the delivery unit to the time on target are as follows:

Delivery means	Assumed planning times	Time between successive rounds
Gun	30 minutes	1 round per gun per 15 minutes.
Free rocket	1 hour	1 round per launcher per 30 minutes.
Guided missile	2 hours	1 round per launcher per hour.
Aircraft	*4 hours	Not applicable.

*In the case of aircraft strikes, when aircraft are on ground alert, use 60 minutes (including 30 minutes flight time)

When requesting air delivery of weapons or delivery by means under control of a higher headquarters, additional time should be provided for the transmission, consideration, and approval of the request. The times shown are based primarily on the time required to prepare the weapon and delivery means for employment. Calculation of firing data is made concurrently with weapons preparation. Times given are based on the assumption that the weapons are readily available at the firing sites or air bases.

17. (Superseded) Blast Wave Characteristics

The rapidly expanding fireball of an atomic detonation exerts an outward push on a large volume of air. This compressed air continues to move outward from the burst point as a shock wave at a velocity approximately equal to the speed of sound. The leading edge of the blast wave is characterized by an abrupt rise in pressure above atmospheric. The maximum pressure at the *shock front* is called *peak overpressure*. Peak overpressure is expressed in terms of pounds per square inch (psi) above normal atmospheric pressure. Associated with the blast wave are static and dynamic pressures. Overpressure is a measure of the static pressure which tends to engulf and crush target elements. The dynamic pressure tends to pick up or roll target elements along the ground. It is the magnitude of these pressures and their duration which largely determine the degree of damage produced by blast. Following the peak overpressure at the shock front, the pressure gradually drops off to atmospheric, and then below atmospheric, followed by a return to atmospheric pressure (fig. 1). That portion of the blast wave in which the pressure is above atmospheric—the positive pressure phase—is most significant from the point of view of blast damage; however, the negative phase may contribute to damage of some target elements.

19. Target Response to Blast

a. (Superseded) *Personnel.* Personnel can be injured by blast in two ways. Primary blast injuries result from the direct action of the blast pressures on the human body. Secondary blast injuries result from collapsing buildings, debris, or equipment flung about by the blast, or from personnel being picked up and hurled against stationary objects on the ground. It requires a great deal of pressure to cause significant body injury from pressure alone. Since other casualty producing effects generally extend farther, primary blast injuries are not significant from the point of view of personnel casualties. On the

other hand, the pressures required to create conditions in which secondary blast injuries are likely to occur are relatively low. Therefore, secondary blast injuries are significant.

b. (Superseded) *Military Equipment.* All types of military equipment can be damaged by blast if the peak overpressures are high enough; however, they are most vulnerable to dynamic pressures. Wheeled vehicle damage, considering only damage severe enough to render the vehicle unusable, consists of frame distortion, and wheel, body, and engine damage. Overturning contributes to damage. If fuel tanks rupture, fire damage may also occur. Armored vehicles are very resistant to blast; however, they may be damaged when dynamic pressures are high enough. Overturning of armored vehicles resulting in damage to sighting equipment and gun mounts usually renders the vehicle or tank unusable. Artillery is damaged in much the same manner as tanks. Lighter weapons and field equipment, due to the ease with which they are blown about, are damaged at greater distances from the burst than heavier equipment.

c. (Superseded) *Bridges.* Bridges are quite resistant to air blast. Very high *dynamic pressures* are required to damage bridges to the point where they are no longer usable. Steel military bridges * * * are more vulnerable.

* * * * *

25. Characteristics of Prompt Nuclear Radiation

* * * * *

b. (Superseded) *Gamma Radiation.* Gamma radiation is very penetrating; clothing, thin walls, or minor irregularities in the terrain offer negligible protection. Shielding from gamma radiation is most effective when the shielding material is of considerable thickness and completely surrounds the personnel. Gamma radiation, as it passes through the atmosphere, is absorbed and scattered. The absorption reduces the amount of the gamma radiation as distance from ground zero increases. Scattering of the gamma radiation means that some (about 10 percent) is deflected from its straight path and appears from all directions. An individual behind a stone wall, for example, though well protected from thermal radiation, would be only partially protected from gamma radiation. An individual in a foxhole receives about one-tenth of the gamma radiation which is present outside the foxhole.

* * * * *

32. Neutron Induced Gamma Activity

* * * * *

c. (Added) The fractions of the 1-hour dose rates of neutron induced gamma activity remaining at selected times after detonation are shown in table IVa.

TABLE IVa. (Added) Decay Factors for Neutron Induced Gamma Activity

Time after detonation in hours	Fraction of dose rate at 1 hour	Time after detonation in hours	Fraction of dose rate at 1 hour
1	1.00	12	0.57
2	0.95	18	0.40
3	0.90	24	0.30
4	0.80	30	0.20
5	0.77	36	0.16
6	0.73	48	0.085
8	0.70	60	0.067
10	0.63	72	0.023

42. Description of Atomic Damage Template

* * * * *

c. The two damage * * * other unarmored vehicles. The radii of these circles were obtained from table VII, and as pointed out in paragraph 38 indicate the distance from ground zero at which the probability of damage is 50 percent. Examination of figure 5 indicates that the probability of damage within the circle will vary from practically 100 percent at ground zero to 50 percent at the damage radius and that some damage will be expected beyond the damage radius. Actually, about 85 percent of all the target elements within the damage circle applicable to that type of target will be damaged. **The 15 percent escaping damage within the circle will be offset by the number of target elements damaged outside the circle.** These figures, while * * * outside the circle.

* * * * *

43. (Superseded) Use of Atomic Damage Template

a. General. The ADT method is the use of atomic damage templates in conjunction with the situation map to evaluate possible atomic weapon employment. The templates do not give a complete picture of the effects of atomic weapons on a tactical target, but they do give the basic information which will usually be required in planning for the use of atomic weapons. For normal employment, the effectiveness of an atomic weapon against a given target can be judged by placing the template over the representation of the target

on the situation map. If templates for the available weapons are placed one after the other on the prospective target, it will be possible to judge what weapon and burst point promise the most satisfactory damage to the target without undue risk to friendly troops or use of excessive amounts of fissionable material. If time permits, calculations can be made of the damage which may occur on the target and the probability of its occurrence; however, an acceptable decision concerning desired yield and burst point can usually be made from the visual inspection alone.

Typical templates included in this pamphlet are for low air-burst heights since this height of burst is the one which normally provides the best overall damage to tactical targets composed of both personnel and equipment. **Templates can be prepared for appropriate map scales** using the damage and casualty radii in tables VII and VIII respectively, and the safety radii presented in table IX.

* * * * *

45. Template Construction (Rescinded)

48. *Point Targets—Nonzero CEP*

* * * * *

b. Examples of the use of figure 11 are given below.

* * * * *

(1) *Given:* * * *

Answer: Probability (P) of damaging target=0.72 or 72 percent (fig. 11).

* * * * *

[AG 461 (24 May 56)]

52. Fractional Damage for Circular Targets—Zero CEP

a. Just as for * * * probability is involved. The technique of using figure 13 consists of substituting for CEP in the ratio $\frac{CEP}{R_T}$, the value of the distance (d) from target center to the actual ground zero, and then reading the f contours at the intersection of the values for $\frac{R_D}{R_T}$ and $\frac{d}{R_T}$. Interpolation may be * * * (f) are likely.

* * * * *

63. Buffer Distance

* * * * *

b. (*Superseded*) *When friendly troops* are disposed in essentially a straight line, a buffer distance equal to twice the CEP (2 CEP), when added to the safety radius for the appropriate risk and vulnerability conditions, gives a minimum safe distance for which there is at least a 99 percent assurance that the specified risk will not be exceeded. If there is considerable curvature in the outline of friendly troop positions around desired ground zero, e. g., an enemy penetration, or friendly troops have surrounded a strong point, select a buffer distance equal to 2½ times the CEP (2.5 CEP). This buffer distance, likewise, when added to the safety radius gives a minimum safe distance for which there is at least a 99 percent assurance that the specified risk will not be exceeded.

* * * * * * *

By Order of *Wilber M. Brucker*, Secretary of the Army:

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MDW	US Army Engr Sch	Mil Dist
ZI Armies	PMG Sch, US Army	MAAG
Corps	US Army Arty & GM Sch	Mil Msn
Div	US Army Qm Sch	ARMA

NG: State AG; Div; Brig; Regt/Gp; Bn.
USAR: USAR Sch; units—same as Active Army.
For explanation of abbreviations used, see SR 320-50-1.

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